MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

DTIC

①

AD-A151 691

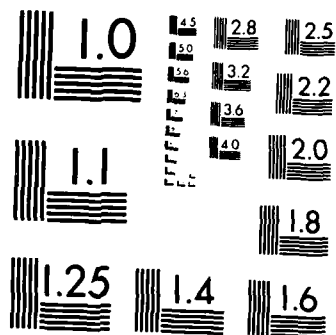COMPUTERIZED BIOPHYSICAL DATA ACQUISITION
SYSTEM FOR MOTION SICKNESS STUDIES

THESIS   Douglas G. Fitzpatrick
                          Capt   USAF

Michael A. Rogers   Robert Williams
Capt   USAF   Capt   USAF

AFIT/GE/GCS/ENG/84D-30

DTIC FILE COPY

DTIC
ELECTE
S   D
MAR 28 1985

B

DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

85   03   13   133

AFIT/GE/GCS/ENG/84D-30

COMPUTERIZED BIOPHYSICAL DATA ACQUISITION
SYSTEM FOR MOTION SICKNESS STUDIES

THESIS   Douglas G. Fitzpatrick
                  Capt USAF

Michael A. Rogers   Robert Williams
Capt USAF   Capt USAF

AFIT/GE/GCS/ENG/84D-30 ✓

DTIC
SELECTED
MAR 2 8 1985

B

AFIT/GE/GCS/ENG/84D-30

COMPUTERIZED BIOPHYSICAL DATA ACQUISTION
SYSTEM FOR MOTION SICKNESS STUDIES

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science of Electrical Engineering

Douglas G. Fitzpatrick
Captain, USAF

Michael A. Rogers   Robert Williams
Captain, USAF   Captain, USAF

December 1984

Preface

The goal of this thesis project was to integrate a biophysical data acquisition system with a MASSCOMP MC500 computer to provide the foundation for a computerized motion sickness rehabilitation program. We would like to take this opportunity to express our gratitude to some of those who helped us reach our goal.

We would like to thank the U.S. Air Force for giving us the opportunity to pursue our advanced degrees at such a distinguished institution as AFIT. Also we would like to express our appreciation to the people in the AFIT Fabrication Shop and Electrical Engineering Lab for their time and technical expertise.

We would like to express a special thanks to our thesis advisor, Dr. Matthew Kabrisky, for his guidance and patience. We are also grateful to Dr. William Czelen for sharing his biomedical engineering knowledge with us.

It is impossible to mention all of the others who provided support to our study but we want all to know we are deeply grateful for all the help we received.

Finally, we wish to extend our heartfelt gratitude and love to our wonderful children and beautiful wives Norma, Terri, and Diane for their love, understanding and support in helping us complete our studies at AFIT.

Table of Contents

List of Figures

Abstract

A biophysical data acquisition system was integrated with a MASSCOMP MC500 computer to provide the foundation for a computerized motion sickness rehabilitation program.

A user-friendly data acquisition system was developed to process several different channels of biophysical information from a subject. This system processes the data to create graphics for operator interaction on a real-time basis and stores data for later retrieval and analysis.

The electrical schematics and frequency responses of the fabricated physiological monitoring equipment used to measure heart rate, gastric motility, respiration rate, skin pallor, intestinal tone, and eye movement were completed.

COMPUTERIZED BIOPHYSICAL DATA ACQUISITION
SYSTEM FOR MOTION SICKNESS STUDIES

I. Introduction

Background

Widely publicized occurrences of motion sickness among astronauts during recent space shuttle flights have generated renewed interest in how to deal with the motion sickness problem.

This problem of motion sickness has been approached from two sides; prevention and rehabilitation. Studies on preventing Motion Sickness Incidence (MSI) are ongoing and have met with mixed success. They range from studies on the effects of MSI suppressant drugs on aircrew effectiveness to attempts at correlating the frequency components of MSI inducing motion to MSI severity (11).

The other approach is rehabilitation. To that goal a team of flight surgeon psychologists and a biofeedback technician, of the Neuropsychiatry Branch of the USAF School of Aerospace Medicine (SAM) at Brooks AFB, Texas, have reported success rates of 84% in the rehabilitation of aircrew members with chronic disabling motion sickness (18). Their methods are based on the application of biofeedback in Autogenic Feedback Training (AFT). Dr. Patricia Cowings of

NASA-Ames Research Center has also successfully used AFT in her studies (7).

Unfortunately the requirements for specialized training and equipment restricts the availability of this rehabilitation program to Brooks AFB, Texas, so far as the military is concerned. One solution to this restriction would be to automate the AFT technique thus making a computerized rehabilitation program generally available at military bases.

With this goal in mind two AFIT Electrical Engineering students, Capts Orville Earl and Charles Peterson in 1983, successfully constructed a micro-computer based Biophysical Data Acquisition System (BDAS). This system can collect up to 16 different channels of physiological information such as heart rate, gastric motility, respiration rate , galvanic skin response and temperature. It includes a rotating chair, an on-board CIM-800 micro-computer and an off-board MASSCOMP MC500 data acquisition computer. However, because of time limitations, their thesis effort concluded with system construction and did not proceed to integration and operation with test subjects (9).

Problem

This thesis will integrate the BDAS with the MASSCOMP MC500, characterize the fabricated BDAS transducers, and collect data from volunteers for later correlation to MSI.

Scope

The scope of this study will be limited to:

1. the integration of the BDAS with the MASSCOMP MC-500 computer to provide a user friendly data acquisition system and therefore will:

    A. develop a subsystem interface circuit module (SICM) to integrate the BDAS to the MASSCOMP MC500;

    B. develop data collection software for the chair's programmable digital collection equipment (PDCE);

    C. evaluate the MASSCOMP MC500 computer and determine its capabilities;

    D. identify, analyze, and evaluate programming requirements for the BDAS;

    E. design and implement a user friendly data acquisition software system using existing MASSCOMP MC500 computer software as much as possible;

    F. limit the data acquisition software system to:

        1) a user friendly menu driven data collection program;

        2) process the data to create graphics for operator interaction on a real-time basis;

        3) store data for later retrieval and analysis.

2. the characterization of the Physiological Monitoring Equipment (PME) to involve:

    A. drawing the electrical schematics;

    B. determining the frequency responses.

3. the collection of biophysical data from volunteers for later correlation to MSI.

Assumptions

The basic assumption is that a correlation exists between biophysical data collected by the BDAS and MSI, based on reports of a similar nature (19, 24).

Another assumption is that AFT can be automated as a reliable substitute for the experience of a trained AFT medical team.

No assumptions are made that the roots of motion sickness are psychological and no assumptions are made as to how soon before the process of emesis becomes irreversible that analysis can be completed.

Summary of Current Knowledge

Researchers have approached the problem of motion sickness in several ways. One approach is to desensitize the sufferer through continued exposure to the motion sickness inducing environment coupled with professional psychiatric counseling. Another approach is to use MSI suppressant drugs (27) or study the correlation between the frequency components of the motion and the incidence of motion sickness (11). The results of these approaches have been mixed. A more recent approach that has met with success is the rehabilitation of the motion sickness sufferer through biofeedback training.

Dr. Richard Levy, of the USAF School of Aerospace Medicine in Brooks AFB, Texas, reports success in clinical application of biofeedback for a range of disorders

To transmit the 16 bit result to the MAC (collection function #4), the PDCE sends the data to the Parallel I/O board which:

1. places 16 bit data on the output lines;

2. generates a parity bit from the data;

3. generates H1, which signals the receiving subsytem that new data is available;

4. resets H1 upon receiving an H2, a signal to the PDCE that data was received; and

5. returns to step 1.

Parallel I/O Timing Relationship. This section describes the timing requirements of the parallel I/O circuit which consists of a 16 bit data output port and a 2 signal (H1 and H2) handshaking port (9).

As seen in figure 3.1, H1 is the parallel I/O circuit's transmit handshake signal which is sent high (5 volts) when data is outputted and returned low (ground) when the circuit detects a receive handshake signal, H2.

Unlike most handshaking schemes, H1 does not guarantee the validity of the data either on its rising or falling edge nor does the parallel I/O circuit hold back the transmission of new data for a slow receiver. It is up to the designer to develop the appropriate receiving circuitry to guarantee data validity and to prevent interface deadlocks which occur if the transmission rate exceeds the receiver's processing capabilities.

III. _System Integration_

To interface the chair and MAC subsystems, a Subsystems Interface Circuit Module (SICM) was developed to satisfy the different interface requirement of each subsytem. This section describes the chair-MAC interface requirements and the resulting SICM design and operation.

Chair Subsystem Interface Overview

The rotating chair interfaces to the MAC through sliprings via an onboard Programmable Digital Collection Equipment (PDCE) composed of:

1. a Z80-type NSC800 CPU (6);

2. RAM and ROM memory to hold the digital collection software (1);

3. Analog to Digital Converter (ADC) to convert analog subject data to digital form (3);

4. input/output ports for transferring 16 bit data to the MAC and for communicating with a remote terminal (2); and

5. battery power supply (4)

for performing the following six data collection functions:

1. select 1 of 16 analog channels to digitize;

2. start the ADC;

3. when digitization is completed, insert 1 of 16 four bit channel IDs in front of the 12 bit digitized transducer data; then

4. output the resulting 16 bit data in parallel to the MAC through two separate 8 bit IO ports; and finally

5. respond to user keyboard input to abort the operation, otherwise return to step 1.

Graphics Routines. The graphics routines of the MASSCOMP control execution of the third M68000 processor. Collectively the graphics subroutines give a user program the ability to create displays separate from the data acquisition and host processor actions. Within the Data Acquisition and Display System (DAADS), subroutine 'initgraphics.c' uses graphics routines to perform initialization, place and control display windows, and create display segments for continuous execution by the graphics processor.

into memory; preventing its being swapped out and ensuring the program is loaded and ready when a real-time event occurs.

MASSCOMP has a hardware configuration specifically designed for real-time data acquisition. The MC500 provides real-time processing by using separate processors for data acquisition, general purpose processing and graphics data display. Each processor works in parallel and is linked through three high speed buses. This independent execution allows simultaneous data acquisition, graphics and general multi-user processing. Thus, unlike standard UNIX, when a data acquisition routine needs CPU attention, the entire system will not stop.

The software controlling the three processors is user programmed in high-order programming languages like C, Fortran or Pascal. MASSCOMP provides subroutines to insulate user programs from the assembly language or bit-level instructions required to control signal converters or graphics output.

Data Acquisition Routines. MASSCOMP data acquisition routines are executed by the second of three M68000 processors. These subroutines give a user's program the ability to initialize or set-up data transfer, do the actual transfer, then close the data acquisition devices. Any transfer can be set-up for either digitized or analog signal type of collection.

2 - 8

latch the data, detect data errors, re-time the interface handshaking signals, and prevent interface deadlocks.

MASSCOMP Capabilities

The special features of the MASSCOMP, an enhanced UNIX Bell Laboratories Version III operation system, three MC68000 processors executing in parallel and high level program subroutines, combine to create capabilities designed specifically for real-time data acquisition and graphics display.

The standard UNIX operating system is designed for multi-user multiprocessing. In this time-sharing environment, the operating system injects execution uncertainties by changing CPU time slices and swapping programs in and out of memory. Because of this, if an executing real-time program is waiting to sense an external event from a real-time device, the standard UNIX could swap out the inactive program. Then, when the event does occur, time is lost reloading the program.

The MASSCOMP MC500 enhanced UNIX adds to the operating system the ability to handle real-time processes closer to "real-time". To do this a fixed priority is assigned to a real-time process. At any time the MC500 selects the highest priority real-time process ready to run and gives it unlimited CPU time. The real-time process continues until it terminates, pauses or is interrupted by a higher priority real-time process. A real-time process can even be locked
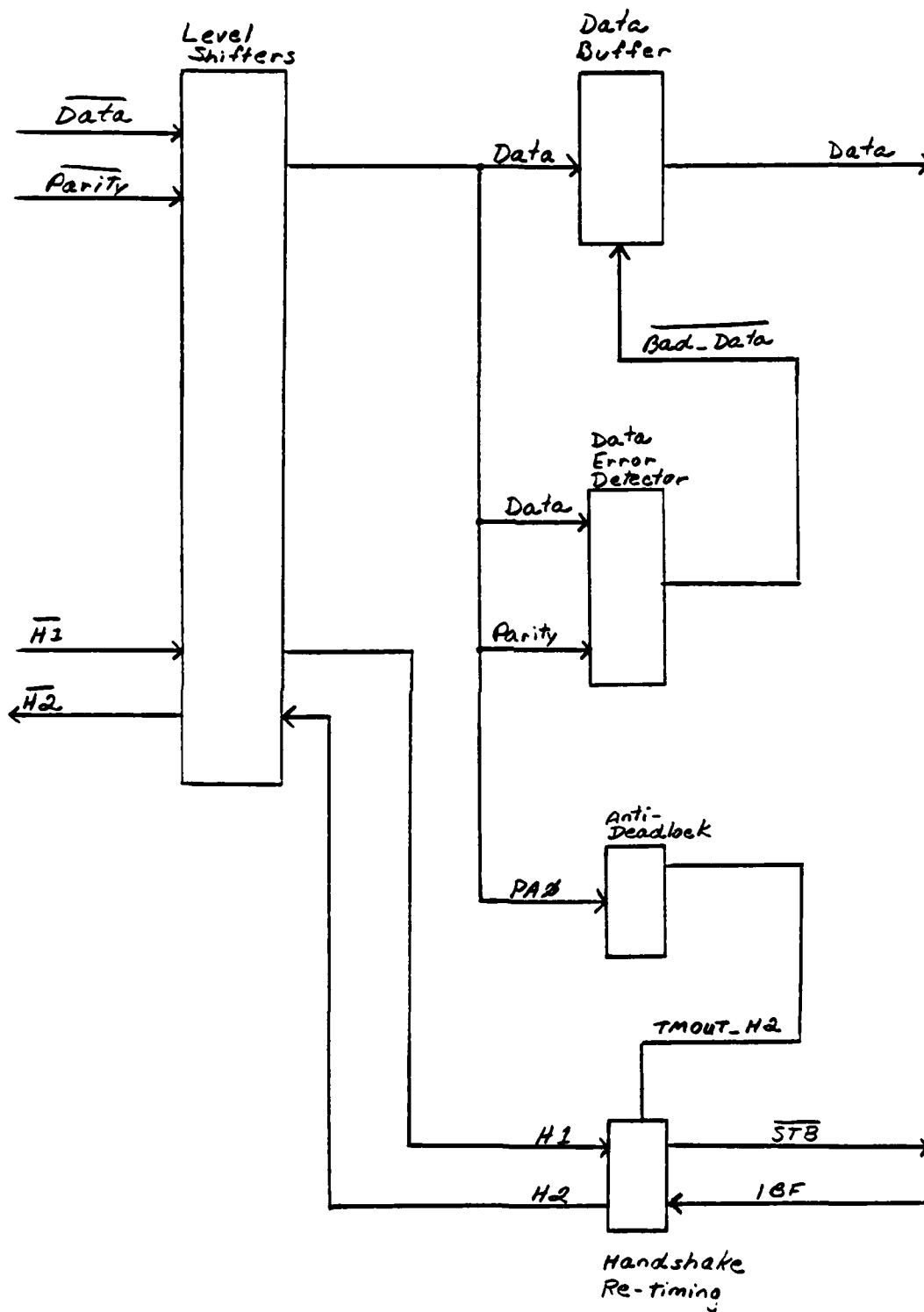
Figure 2.3   SICM Circuit Block Diagram

Subject Input

To record the test subject's preception of his degree of motion sickness, the 1983 team incorporated a variable control input on the chair which is easily reached by the seated subject's right hand (9).

Programmable Digital Collection Equipment

A Programmable Digital Collection Equipment (PDCE) based on the National Semiconductor CIM microcomputer system is installed behind and to the right of the seated subject for processing Autogen, PME, and subject input data. Processing of data requires an onboard Analog to Digital Converter (ADC) circuit to select one of 16 channels for digitization and a digital Parallel Input/Output circuit to transmit the result to the MASSCOMP Analysis Computer (MAC).

Subsystems Interface Circuit Module

Integrating the rotating chair and the MAC required the development of a Subsystems Interface Circuit Module (SICM) to satisfy their differing logic level and timing requirements. The SICM consists of a circuit card and power supply enclosed in a metal chassis which connects between the MAC less than three feet away and through sliprings to the chair more than 30 feet away.

As seen in figure 2.3, the SICM design consists of five major circuits which; level shift the chair-SICM interface,

ECG Electrodes — 2 → ECG — Filtered ECG — 0 — Channel 0 — 1

Thermister → Autogen 1000 Thermometer — Relative Temp. — 1 — Channel 1 — 2

Myograph Electrodes — 3 → Autogen 1100 Feedback Myograph — Absolute EMG — 2 — Channel 2 — 3

Dermograph Electrodes — 3 → Autogen 3000 Feedback Dermograph — GSR Level — 3 — Channel 3 — 4

Dermograph Electrodes — 3 → Autogen 3400 Feedback Dermograph — GSR Response — 4 — Channel 4 — 5

EGG and EIG Electrodes — 3 → EGG and EIG
- Vacant — 5 — Channel 5 — 6
- Vacant — 6 — Channel 6 — 7
- Vacant — 7 — Channel 7 — 8
- EGG — 8 — Channel 8 — 9
- EIG — 9 — Channel 9 — 10

ENG Electrode — 2 → ENG — ENG — 10 — Channel 10 — 11

BPV Transducer — 8 → BPV Photo-Plethysmograph (2 channels)
- BPV 1 — 11 — Channel 11 — 12
- BPV 2 — 12 — Channel 12 — 13

Pneu. Transducer — 4 → Pneumograph (2 channels)
- Pneu. 1 — 13 — Channel 13 — 14
- Pneu. 2 — 14 — Channel 14 — 15

Input Control — 2 → Subject Physiological Awareness Input — Sub Input — 15 — Channel 15 — 16

TV Monitor — Rf Output → Autogen 9400 Matrix Feedback
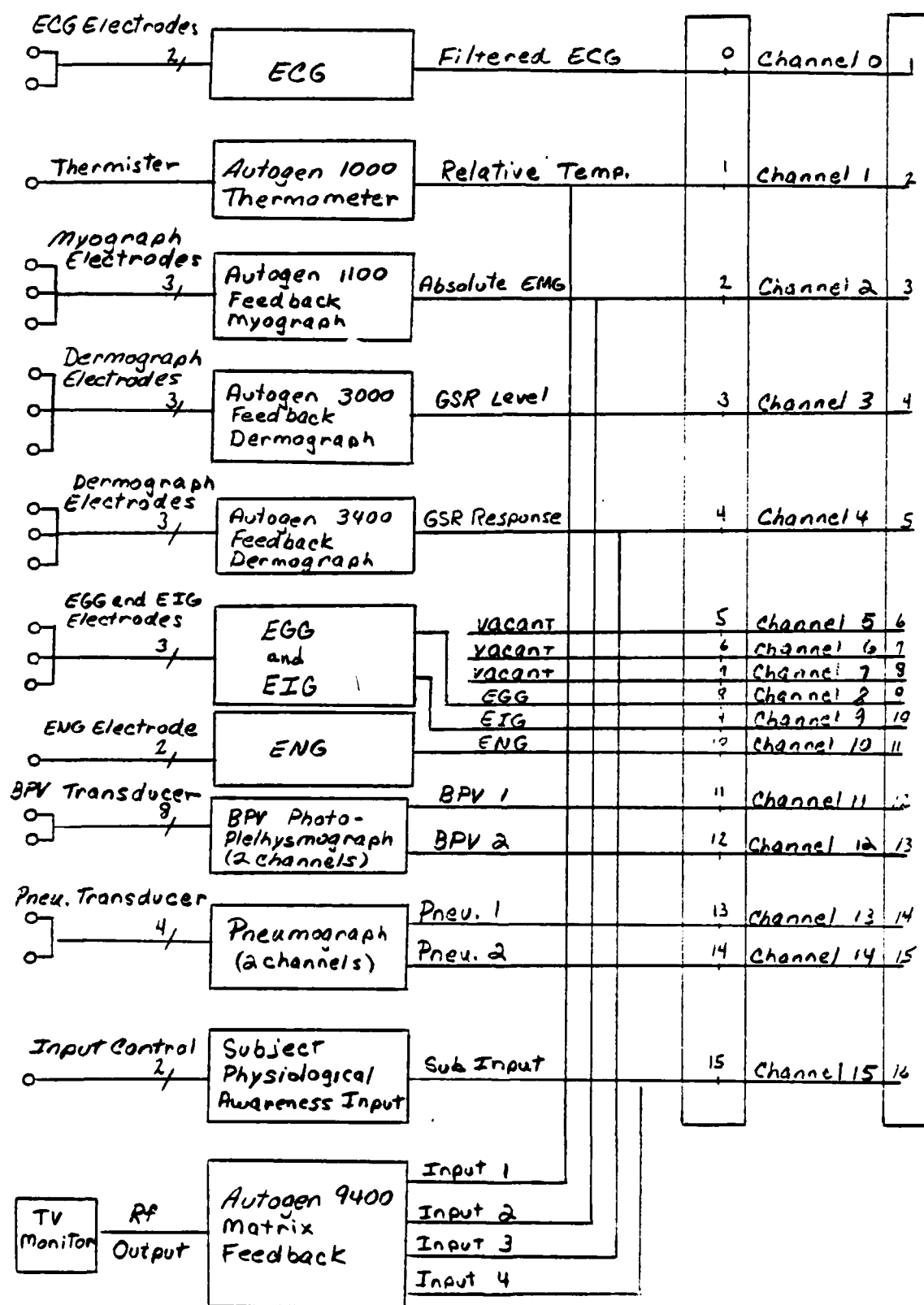- Input 1
- Input 2
- Input 3
- Input 4

Figure 2.2 Biophysical Acquisition System Block Diagram

programmable digital collection equipment (PDCE) to collect and transfer biophysical data.

Autogen Corporation Biofeedback Equipment

The Autogen Corporation equipment installed behind the seated subject collects additional biophysical data which consists of:

1. Autogen 1000 feedback thermometer for measuring relative skin surface temperature;

2. Autogen 1100 feedback myograph for measuring muscle contractions/relax tions;

3. Autogen 3400 feedback dermograph for measuring a subject's galvanic skin response;

4. Autogen 9400 Programmable Display Matrix to provide a bar graph representation of selected sensor outputs.

Physiological Monitoring Equipment

To augment the Autogen biofeedback equipment, Physiological Monitoring Equipment (PME) was developed and installed behind and to the left of the seated subject to initially provide pulse-to-pulse heart rate (ECG), gastric motility (EGG), respiration rate (pneumograph), and skin pallor (photo-plethysmograph) data (9). Additional transducers were later developed to provide intestinal tone (EIG) and eye movement (ENG) data.

A block diagram of the transducer system is shown in figure 2.2 while the PME characteristics and schematics are discussed in Appendix A.
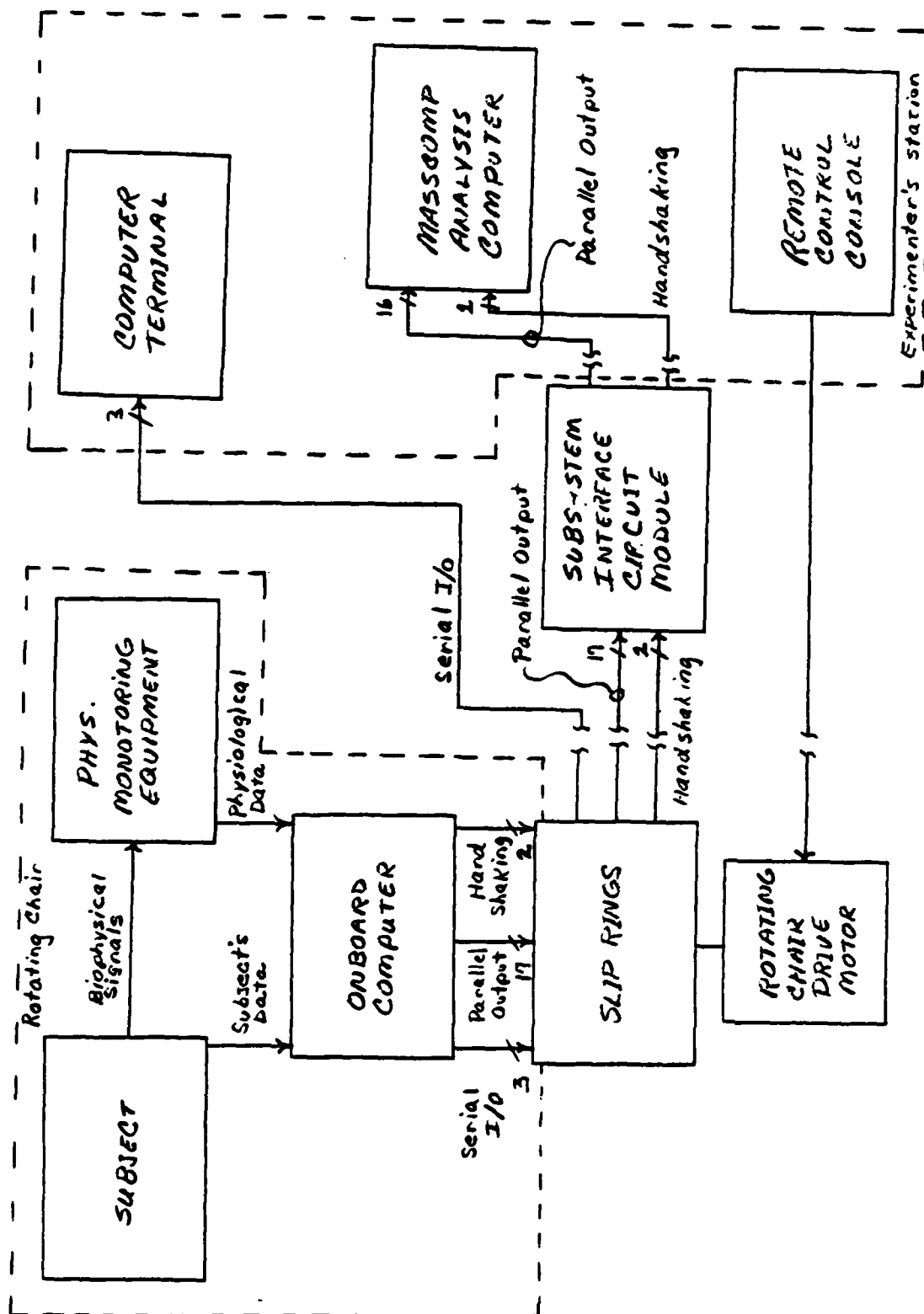
Figure 2.1 Overall System Configuration

II.   System Description

This section describes the function and configuration
of the following seven major Biophysical Data Acquisition
System (BDAS) components:

1.   Rotating Chair

2.   Autogen Corporation biofeedback equipment

3.   Physiological Monitoring Equipment (PME)

4.   Subject Input

5.   Programmable Digital Collection Equipment (PDCE)

6.   Subsystems Interface Circuit Module (SICM)

7.   MASSCOMP Analysis Computer (MAC)

This system rotates a subject in the chair, collects
the subject's response data, and transmits this data to the
experimenter station MAC for processing. A separate console
controls the chair's rotation.

A block diagram of the overall system is shown in
figure 2.1.

Rotating Chair

The multiaxis motion simulator assembled by Capts Earl
and Peterson rotates about the vertical axis while all other
degree of motions and their controls were disabled for the
safety of the subject and protection of the attached elec-
tronic equipment (9).

The attached electronic equipment includes Autogen
equipment, Physiological Monitoring equipment (PME), and

2 - 1

Approach

The approach of this study took the following steps:

1. a literature search was completed in order to understand:

    A. the BDAS;

    B. the MASSCOMP MC500.

2. the transducers were characterized to aid in the development of the data acquisition software system.

3. a hardware interface between the BDAS and the MASSCOMP MC500 computer was constructed to establish the TTL logic levels and timing requirements necessary for the interaction of these two systems.

4. a data acquisition software system was developed to initiate, monitor, and terminate biodata collection under user control. The purpose is to produce a historical data base on each subject for MSI corrrelation studies.

conducted using control groups which were divided into three sections; one which experimented with AFT as a rehabilitation technique, one which experimented with cognitive tasking (e.g. playing a distracting card game while in a spinning chair), and a group which experimented with desensitization (26).

The results showed that the desensitization approach to motion sickness rehabilitation largely depended on a "stable" stress environment which is not normally realizable in a mission environment. The cognitive task control group proved to be vulnerable to changes in the stressing environment also (e.g. abrupt changes in the chair's rotational rates). The AFT group, however, showed as much as a three-fold improvemnet in rehabilitation over that of the other two control groups (26).

Based on the successes of of Dr. Levy and Cowings, two AFIT graduate students, Capts Orville Earl and Charles Peterson in 1983, successfully developed a Biophysical Data Acquisition System (BDAS) which monitors biophysical parameters believed to be reliable Motion Sickness Incidence (MSI) indicators (9).

This BDAS is believed to be the only system of its kind in the country. Successful integration of the BDAS with the MASSCOMP MC500 computer will automate the motion sickness rehabilitation program currently implemented at Brooks AFB, Texas.

including motion sickness. He notes that biofeedback provides the subject with real-time information about his physiological functions which he then learns to control. It is by learning to control and subsequently suppressing these physiological functions that allows the subject to control his motion sickness (17).

This technique is not without controversy. Some people question the effect AFT equipment has on the final results. Also the possibility of a placebo effect is not ruled out by some critics. However, Dr. Levy asserts that the equipment helps the subject see the biofeedback process in action and thereby gain valuable reassurance that the technique is not "black magic" (17).

Despite apparent successes by Dr. Levy and others, notably Dr. Patricia Cowings of the NASA-Ames Research Center, additional questions arise as to whether biofeedback really works. Another question raised is that the apparent successes in clinical applications of biofeedback might be attributed to a combination of desensitization and distraction; distraction brought about by requiring the subject to focus attention on equipment readings, thereby taking the subject's mind off the distressful feelings of motion sickness and desensitization by repeated exposure to the stressing environment until the body adjusts to the discomfort (26).

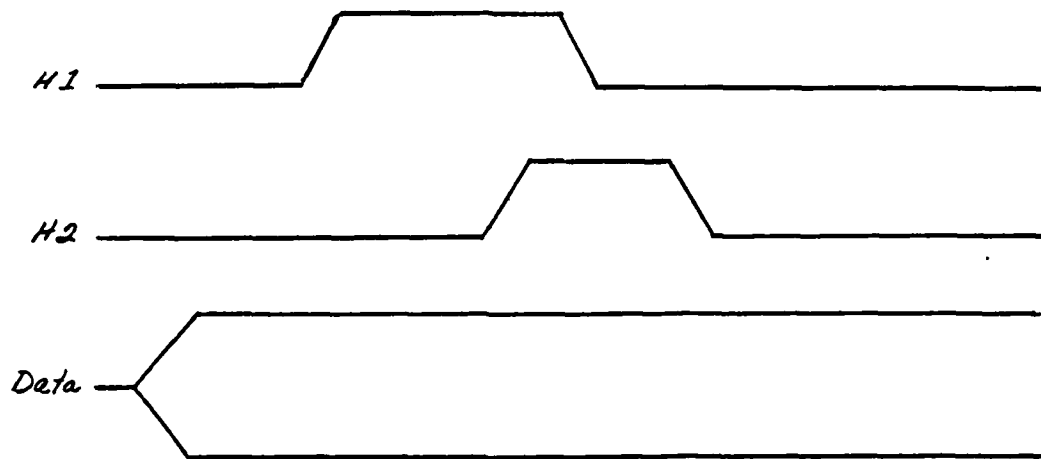Dr. Cowings addresses these questions in a recent study

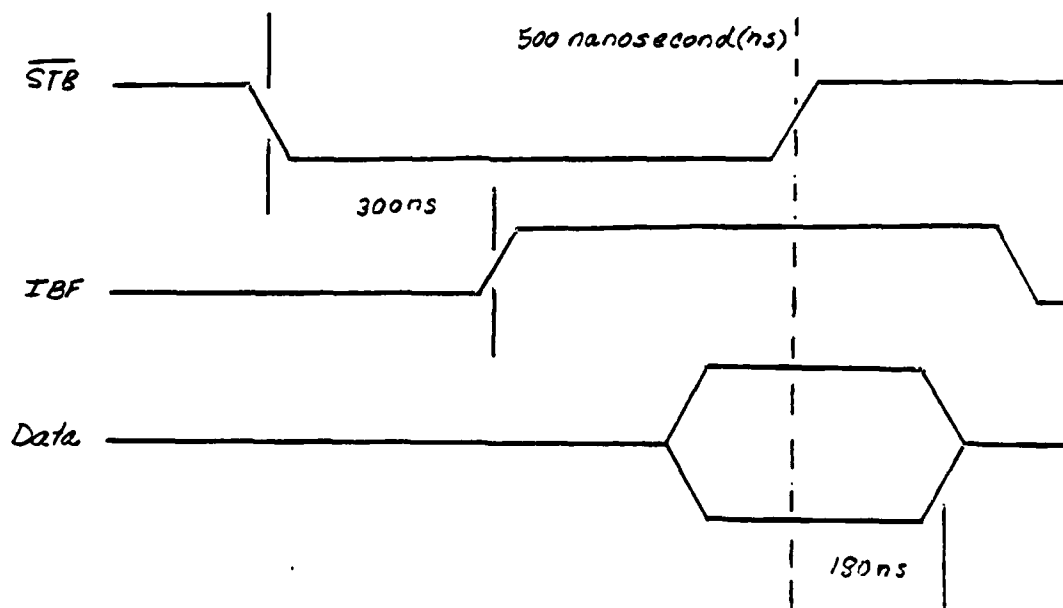Figure 3.1a   Chair Output Timing Characteristics

Figure 3.1b   MAC Input Timing Requirements

3 - 3

MAC Subsystem Interface Overview

The MAC digital I/O interface is based on the INTEL 8255 Programmable Peripheral Interface input mode 2 (21), which consists of:

1. 16 bit parallel data;

2. an active-low Strobe (*STB) pulse to signal the MAC that input data is available;

3. an active-high Input Buffer Full (IBF) pulse to signal the transmitter that the MAC received the data; and

4. a common signal reference ground.

MAC Interface Timing Relationship. The interface illustrated in figure 3.1 functions as follows:

1. initially, the MAC interface must sense a high *STB input while asserting its output IBF low;

2. sensing input *STB low (signalling that data is available), the MAC sends IBF high to indicate that it is ready to accept the data;

3. *STB then goes high to indicate that the data is valid;

4. when the MAC detects that the handshake input, *STB, has gone high,i.e. the data is valid, it buffers the data and drops IBF low to signal that its input buffer is full; and

5. the process continues with step 1 as long as data is available.

Subsystems Interface Circuit Module Operation

This section describes the operations of the Subsystems Interface Circuit Module (SICM) which provides the interface compatibility necessary for communications between the chair and the MAC. Five SICM circuits level-shift the

chair and MAC signals, buffer the data, detect data errors, generate compatible timing signals, and prevent interface deadlocks.

Initially, the chair outputs to the SICM a 16 bit data word, a parity bit, and an transmit handshake signal, H1, at RS232 levels. The SICM then level shifts the chair outputs to TTL levels before routing the data to its internal data buffers and error detection circuits.

While the data are stabilizing at the data buffer inputs, it is also passed through the detection circuit to generate a SICM parity bit from the data to compare against the parity bit received from the chair. And while the SICM parity bit is being generated, the SICM handshake timing circuit converts the chair's transmit handshake, H1, into a MAC handshake signal, *STB, telling the MAC that data are available. A derivative of *STB also latches both the stabilized data and the results of the parity bit test. Whether the MAC inputs data or an error code, depends on the result of the parity bit test. If the two parity bits do not match, a parity error signal converts the data into an error code which the MAC inputs instead of data.

Detecting an input *STB, the MAC inputs the data (or error code) and returns the receive handshake signal, IBF. The SICM handshake-timing and level-shifting circuits convert IFB into H2 for transmission to the chair.

A SICM anti-deadlocking circuit constantly monitors the

interface activity to prevent an interface deadlock from occurring. Deadlock can occur if the MAC-SICM interface fails to respond to a chair's H1 with an H2 before the next H1 occurs. The SICM circuit prevents a deadlock by triggering a delay signal of sufficient duration to allow for a MAC response. If the circuit does not detect a MAC response within this delay window, the SICM produces an H2 of its own to prevent a deadlock situation.

Subsystems Interface Circuit Module Design

From the previous interface requirements and operational descriptions, one observes that the SICM design, as illustrated in figure 3.2, must perform the following six interface functions:

1. provide input and output level shifting between the incompatible TTL and RS232 levels of each interface;

2. provide for pinout compatibility for cable connectors;

3. ensure a data error detection capability;

4. accomodate the differing timing requirements of the chair's H1 and the MAC's *STB transmit handshake;

5. accomodate the differing timing requirements of the chair's H2 and the MAC's *STB receive handshake; and

6. provide for an interface deadlock detection-correction capability.

Level Shifting. The most obvious interface incompatibility is that the chair transmits and receives signals at the RS232 levels to minimize the effects of noise and
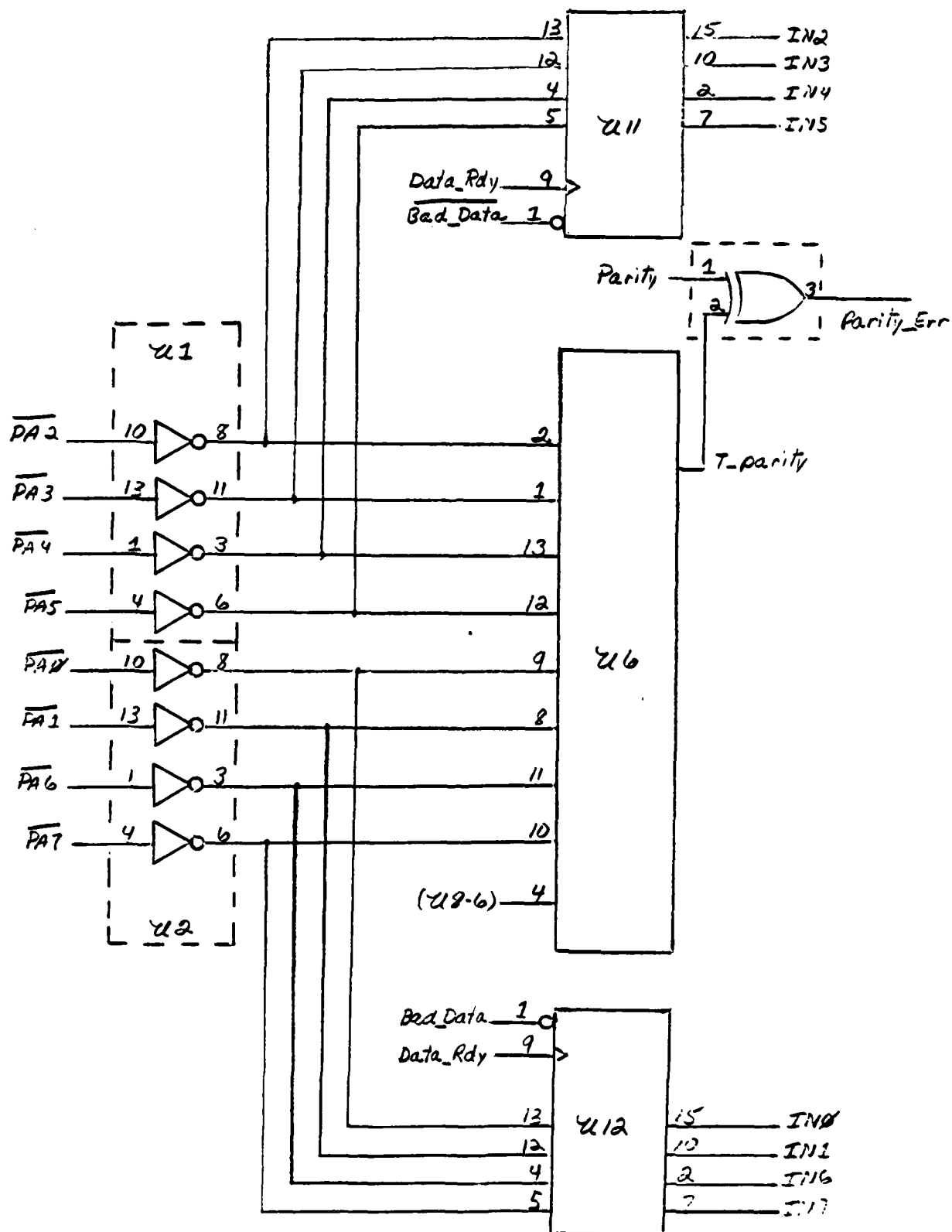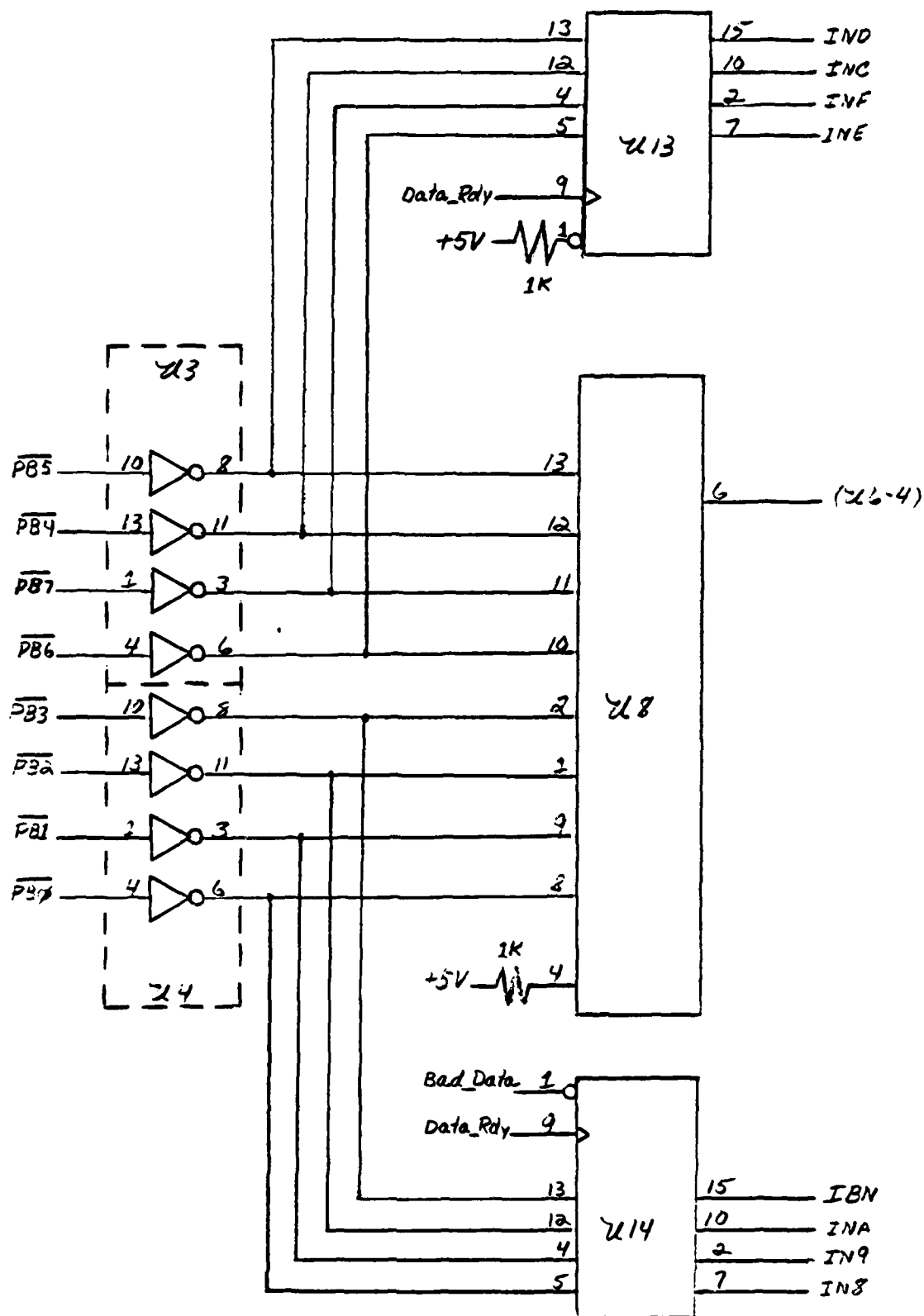
Figure 3.2   SICM Circuit Schematic

3 - 7

Figure 3.2 SICM Circuit Schematic (Cont)

3 - 8
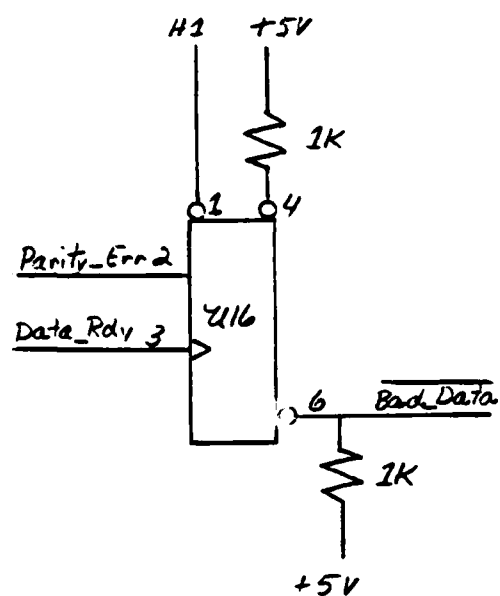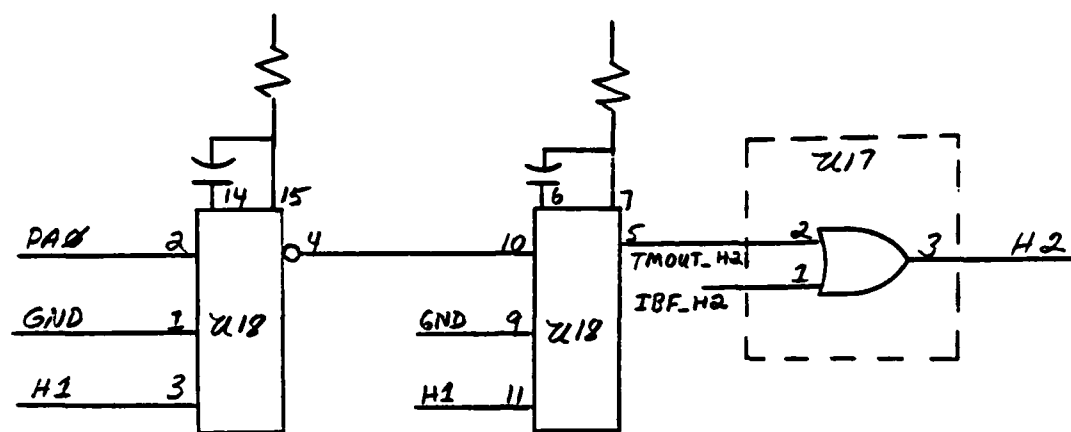
Figure 3.2   SICM Circuit Schematic (Cont)
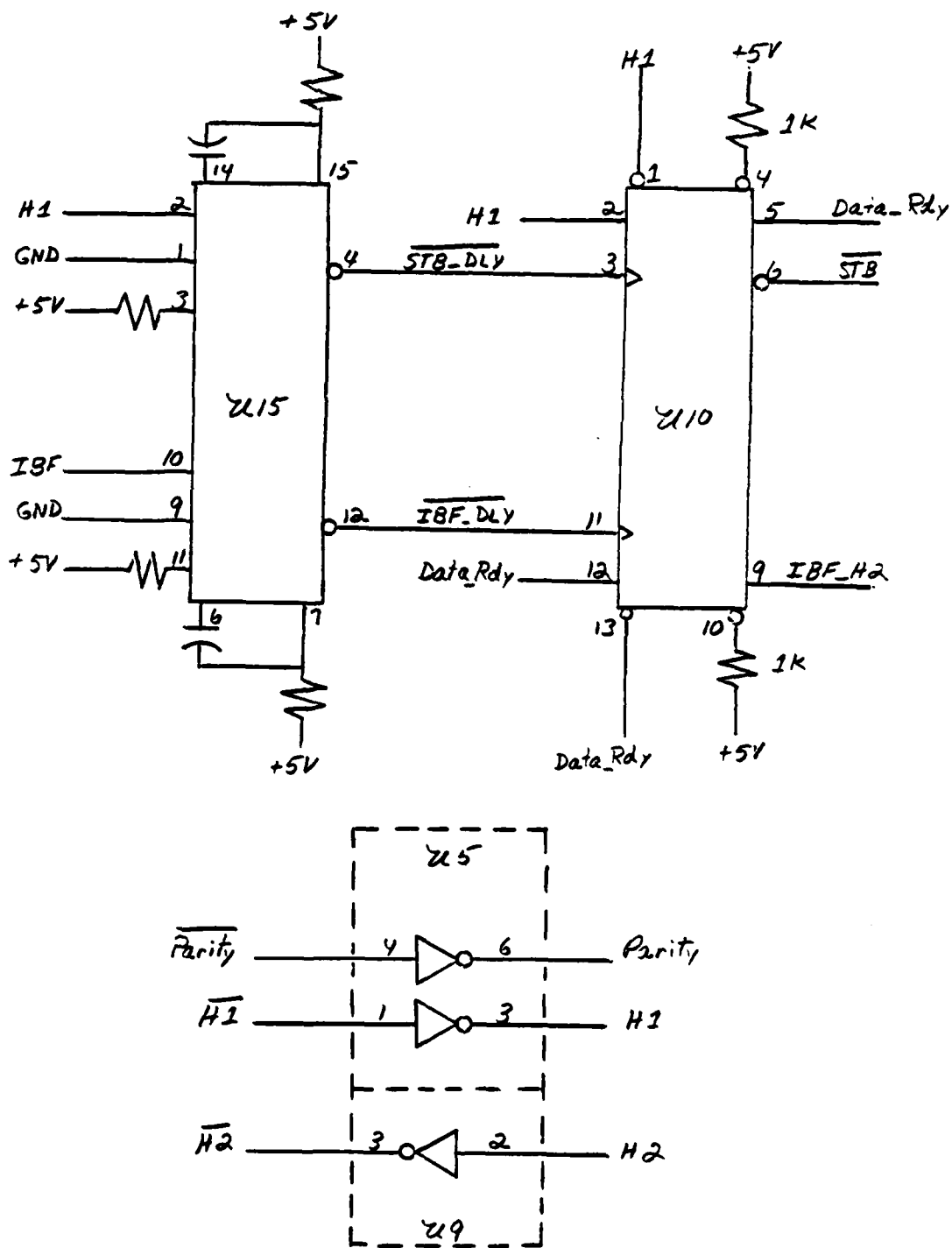
Figure 3.2   SICM Circuit Schematic (Cont)

slipring degradation while   the MAC transmits and receives signals at TTL levels.

As seen in figure 3.2,   the SICM uses five 4 bit MC1489 RS232-to-TTL   level (U1-U5) to convert chair input data   and control   signals to TTL levels and one 4 bit MC1488   TTL-to-RS232   level   shifter (U9) to convert   MAC's   single   output signal (IBF) to RS232.

Pinout Compatibility.   The chair interface consists of 16 data signals,   3 control signals,   and a ground while the MAC   interface has one less control signal (parity).   Additionally,   the data,   control,   and ground lines for the respective interfaces are found at different pin location with different labeling conventions.

The   SICM resolves this incompatibility at the   respective connector pinouts by appropriate rewiring.

Error Detection.   Chair provides a parity bit for   16-bit   data error detection;   however,   the MAC interface does not provide for a parity bit.   The solution is for the SICM to   generate a parity of its own from the data received   and to compare it against the chair's parity bit.   If they   are equal,   the   SICM   transmits the data to the MAC   unchanged; otherwise,   the   SICM sends a 16 bit error code to   the   MAC consisting of an intact 4 bit channel ID field plus a zeroed 12 bit data field.

To generate the error code, the level-shifted data word is   sent to two 74280 parity bit generators   (U6,   U8).   The

lower 8 bits (PAO-PA7) go to U6 while the upper 8 bits (PBO-PB7) go to U8. The 16 bits propagate through both chips to produce a single parity bit. This parity bit, T-parity, is sent to an exclusive-OR gate (U7-2) which compares it against parity from U5-6. The output, Parity_Err, is high if an error exist else it is low. Parity_Err is then latched into U16-2 by Data_Rdy (U11-9) to produce *Bad_Data (U16-6) as an input to pins 1 of data latches U11, U12, and U14. If *Bad_Data is true,i.e. logic 0, the 12 data bits are cleared while the upper 4 bit channel ID field of U13 remain uneffected to produce the 16 bit error code. Valid zero data codes are possible but as they represent saturated data, the effect would be similar.

The error detection circuit can be disabled if desired by removing U16 from the circuit card. A 1K ohm pull-up resistor was installed at U16-6 which will maintain *Bad_Data at the required false level if U16 is removed.

H1 To *STB Timing. H1 and *STB are the transmit hand-shake signals for the chair and MAC respectively (figure 3.3). Because the chair interface was developed before the MAC interface documentation was available, the two are not compatible. The SICM produces a MAC *STB signal from the chair's H1 as follows:

1. the rising edge of H1 (U15-2) triggers a oneshot, *STB_Dly (U15-4), producing a negative pulse of approximately 9 microseconds which allows data to stabilize;
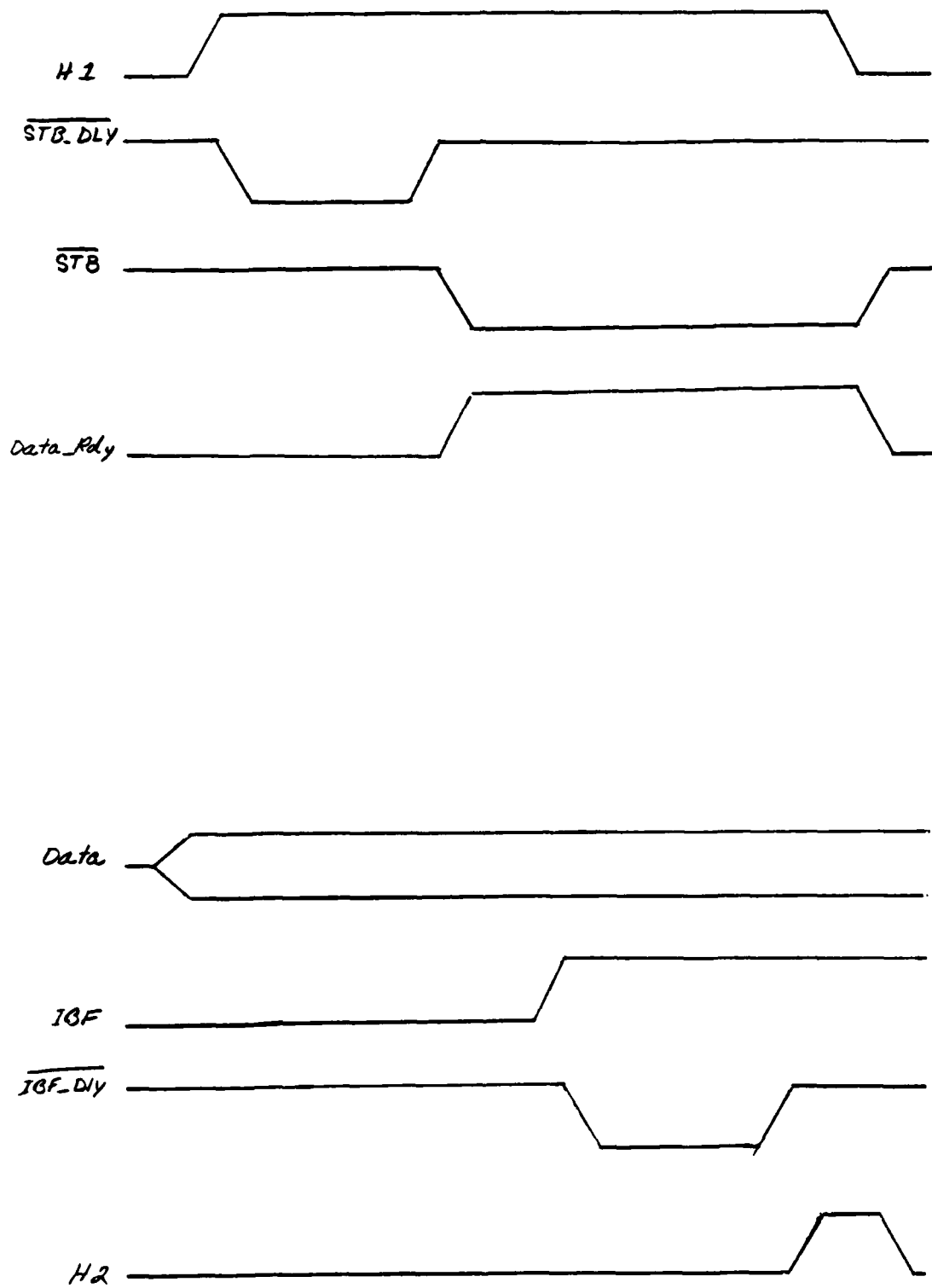
Figure 3.3   Chair-MAC Interface Timing

3 - 13

2. this oneshot latches H1 into U10 on timeout to generate a *STB (U10-6) and a Data_Rdy (U10-5) where Data_Rdy minimizes the possibilities of spurious noise on H1 from inadvertently triggering a handshake to the MAC; and then while

3. *STB is sent to the MAC, Data_Rdy latches the stabilized data into four 4 bit 74175 output buffers (U11-U14) and enables the H2 circuit (U10-U13).

The 74175 chips were found to be sufficient for driving the data outputs to the MAC, thereby reducing the chip count by eliminating the need for three 74244 driver chips.

IBF to H2 Timing. IBF and H2 are the receiving handshake signals of the MAC and the chair respectively. These two are also incompatible and the SICM produces an H2 from the IBF as follows:

1. the rising edge of IBF (U15-10) triggers a oneshot delay, *IBF_Dly (U15-12), to give the MAC additional time to process the data;

2. this oneshot latches Data_Rdy (U10-13) on timeout to generate IBF_H2 (U10-9) which when received by the chair causes H1 to reset; where

3. H1 (U10-1) then resets Data_Rdy (U10-5) which in turn resets IBF_H2 (H10-9).

Interface Deadlock. The Parallel I/O design did not forsee a transmission problem which was discovered when the chair - MAC integration process began and continuous data collection was attempted.

Current data collection procedures require continuously running the chair PDCE while sampling and outputting data; the returning receive handshake, H2, however, is not designed to control H1, the transmit handshake (9).

3 - 14

The project encountered deadlock problems unique to MAC when the MAC received a buffer and suspended further data reception until the buffer was processed. In the meantime, the PDCE continued to transmit data since no channels were available to control the PDCE from the MAC. This results in H1 being set high while waiting for another H2 (which might not appear for milliseconds.)

When MAC returns for more data, it looks for the rising edge of H1 which it never sees since it was missed while processing the previous buffer. The chair, meanwhile, is waiting for the H2 to the original H1 which it will not see since the MAC is still waiting for H1. This results in a deadlock of the interface.

The solution was to trigger a deadlock one shot which generates an unlocking pseudo-H2 to reset H1. The simplest method is to monitor PAO (U18-2), normally the most active data bit. The rising edge of PAO triggers a oneshot delay (U18-4) which produces a 100 microsecond negative pulse, sufficiently long as not to interfere with the normal H1-H2 handshake timing.

Timeout triggers another oneshot pulse, TMOUT_H2 (U1-5) which is an anti-deadlocking input to U17. The other input (U17-1) is IBF_H2. The output of U17, H2, minimizes the chance of deadlock. The deadlock circuit is reset by H1 going low at U18-3 and U18-11 as a response to H2.

Deadlock is possible, however, in the absence of an

3 - 15

IBF_H2 if PAO is inactive (which fails to activate TMOUT_H2) either because of an unusually stable data pattern or a digital fault.

a key signalling it to return to MAIN.

Digchn. The Digchn module is called by Datacq to collect user-selected channels at user-selected sample rates.

When called, Digchn decrements a sample rate counter to determine if selected channels will be sampled during the current pass. If it is nonzero, Digchn jumps to Dmydig which simulates the sampling of all the channels to maintain a fixed sampling interval. Otherwise Digchn reloads the sample rate counter and starts the Analog to Digital Converter (ADC) to sample the selected channels beginning with channel 0. For each channel, a four bit channel ID mask is created to be inserted in front of the 12 bit ADC result for transmission to the MAC.

After each channel, Digchn checks to see if it was the last channel. If not, it gets the next channel, otherwise, it jumps to Dmydig to simulate the remaining channels which maintains the proper sampling interval.

Bitest. The Bitest module allows the user to determine the operational integrity of the chair-MAC interface at any time. This is particularly useful before starting a collection to eliminate the possiblity of collecting data over a faulty interface. Bitest increments and transmits a 16 bit test pattern to the MAC at a fixed rate. The 256 different 16 bit patterns are generated by incrementing an 8 bit count and transmitting the result through the upper and lower 8

Datacq.   The Datacq module is the primary data collec-

tion module in MAIN which:

1.   resets TIMTAG, a data acquisition counter;

2.   selects the number of channels to be collected,
      from 1 to 16;

3.   sets the sample rate for all channels to be
      digitized; and

4.   disables all maskable interrupts

before entering a software loop to continuously call Digchan

and process subject data at user selected rates. Datacq

exits the loop when it detects a user-initiated abort re-

quest, at which time, Datacq returns to MAIN.

Channel Number.   The user may select from 1 to 16

channels for sampling when prompted, by entering the hexa-

decimal representation for the last channel in the sampling

sequence.   The sampling always starts with channel 0 and

ends with the channel selected by the user.

Sample Rate.   The user is then prompted to enter

the sampling rate for all selected channels.   This sampling

rate then applies uniformly to each channel with no

provision to set different rates for different channels.

The maximum sampling rate, 320 Hertz, is selected by

entering '8' when prompted and decreases by modulo 2 to the

lowest rate, 2.5 Hertz, represented by '1'.   By pressing

'X', the user exits the sample rate selection process.

Having set the sample rate, Datacq continuously calls

Digchn to process data until it detects the user pressing

in the study of motion sickness. The design of BDAS lets future module additions attach themselves at this point. Currently, for Data Analysis selection at the main menu level, only a message appears to the user; "This option is not available at this time" indicates the pathway to the analysis module is open but no analysis program exists in the system. The user must select a different option.

PDCS Software Design

Within the PDCS, the software module Main consists of five major submodules; Menu, Datacq, Bitest, Dspacq, and Hlpmsg. The PDCS code resides in hexidecimal addresses F000 through F7FF while the data segments reside in RAM locations 7000 through 710F. PDCS starts controlling the chair's Programmable Digital Collection Equipment at power on condition.

The PDCS powers up executing the production Monitor software always available in the PDCS to maintain system integrity and facilitate future software development. To enter the operational mode, the user executes the "GF000" command which begins the execution of MAIN.

MAIN. MAIN calls Menu which clears the terminal screen and displays a five function menu prompting th user for a selection. The user enters a single character (carriage return is not needed) which is decoded by MAIN. A match will cause execution of the selected module otherwise MAIN reprompts the user to try again.

straight into the output file.

After each extraction, Extractchan cycles back so the user can extract several channels without restarting the entire system.

Replay. DAADS module Replay allows the user to replay, off-line, previously collected biophysical data. The MASSCOMP graphics display is identical to the data display presented during the actual data collection. The Session Header file produced at the original data collection gives Replay the information needed to recreate the graphics.

Replay uses the same Initgraphics routine as Cllctdata. Based on the information in Session Header file, Initgraphics again creates display windows and display segments. Replay then reads the data input file, scales the data and places it into display buffers. Each display buffer represents a data channel. The original collection mode, parallel or analog, determines if internal module para_display or analog_display will process incoming data. The basic difference between the two is how the data are scaled. For parallel data the values range from 0v to +10v. Analog data ranges from -5v to +5v. The Replay module continues execution until the user types any key on the keyboard or until there are no more input data.

Perform Data Analysis. The Perform Data Analysis module, yet to be developed, will provide whatever algorithms are necessary for further biophysical data analysis

session or exit to the main menu - Dacqmnu.

Extractchan. The Extractchan module, the second selection on the DAADS main menu, separates from an existing binary multi-channel file a single channel of data. Extractchan initializes necessary graphics displays and opens user named input and output files. The multi-channel input file contains up to 16 channels. The output file will contain only the data for a specified single channel.

To start, Extractchan asks the user for the input and output filenames, the mode of collection (parallel or analog), how many channels are in the input file and which channel to extract. Channel numbering ranges from 0 to 15.

A note of caution - it is left to the user to keep track of how many channels are in the input file and the collection mode used. The program does not error check the user's keyboard responese. If the user states there are 6 channels in the input file and wants to extract channel 4, Extractchan will obey. However, if the input file really contains anything other than 6 channels, unexpected and definitely incorrect output is produced.

Displaying the data while extracting channel data increases the extraction time. This results from Extractchan not using real-time display techniques as does Cllctdata as those techniques are unnecessary for off-line extraction. Instead, the user has the option to see the data as the extraction progresses or just quickly extract the data

Modules Para_collect and Analog_collect perform basically the same processing except one scales for parallel data and the other scales for analog data.

Within either submodule data are processed in the following steps:

1. For each input buffer, individual channel data items are extracted based on the primary data reduction rates.

2. Each channel data item is screened through a secondary data reduction before placement into a channel data display buffer.

3. Just prior to placement into the display buffer, the data item is scaled to fit within the display window.

4. The input buffer is written to disk. As such, all dat items are stored, not just the data items displayed.

Concurrent to this processing, the graphics processor is executing display segments designed to read the data display buffers and plot the values contained inside. In this manner, each channel data display buffer fits into a single display window. Up to 12 windows, or 12 channels, may be displayed

The primary and secondary data reductions perfromed on the data are explained in detasil in appendix H.

Stop and Exit. The data collection, once started, will continue until the user presses any key on the keyboard or the output file becomes full. In either event, DAADS will branch back to the Cllctdata menu and wait for another user selection. At this point the user can start another

METHOD	ADVANTAGES	DISADVANTAGES
Array	Very fast because all data are placed in a single array buffer	Can not process data during the actual collection.
	Relatively simple.	Amount of data items transfered limited by physical memory.
		Real-time data lost between array processing to empty buffer and be ready to receive more data
File	Uses multibuffering to collect data. When full, buffers transparently written to disk.	Can not process data during the actual collection.
	Save large numbers of samples	Transfer rate is limited to disk transfer rate.
	Buffer control done automatically.	Contiguous files must be used.
Queued	Program control of multibuffered data collection to memory buffers.	User program must permanently save data to a disk file.
	Can process data during the collection enabling immediate use of incoming data.	User program must manage the buffers.

Table 4 - 1.   Three methods of data collection.

matches the data mask.

Unlike the parallel device mode, complete analog device mode set-up needs user selection of several different options. The MASSCOMP AD12F analog module can be set to collect data as unipolar (0 to +10v), or bipolar (-5v to +5v) with channel sampling either sequentially (0,1,2...15), or user specified random (0,2,1,4...) (21:A-8). In addition, the AD12F needs clocks to gate or trigger the data sampling. Consequently, clock set-up routines such as 'mrclk1' (21:Ref-13) and 'mrkclk2' (21:Ref-15), further specify how to set-up the analog transfer.

After set-up, data transfer occurs in one of three ways. Each method, listed in Table 4.1 has its own advantages and disadvantages. The DAADS uses the queued transfer method (21:Ref-112) because of the ability to process data while the transfer is carried out. In this manner, data displays can be real-time through separate simultaneous execution of Data Acquisition and Graphics routines.

Collectdata. Collectdata accomplishes the actual data transfer and then branches to an internal module to perform data reduction, scale the data for display, place the data into a display buffer and write the original data to the user named output file. Because display data scaling is different between parallel and analog inputs, two internal modules process data during the actual collection.

this file must exist and be in the format shown in Appendix F. Data images inside each window are generated through execution of display segments.

Display segments are nothing more than "user created subroutine of graphics commands"(20:8-1). Initgraphics branches to internal routine Create_segment which directs the host processor to create a graphics segment. Host processor execution of 'mgisegcont' (20:8-6,14-90) sends the segment to the graphics processor for continuous execution. At this point the host processor is free from the burden of controlling the graphics display and can initialize remaining DAADS functions such as the Initda subroutine data acquisition function.

Initda. The Initda subroutine uses MASSCOMP Data Acquisition system subroutines to initialize the data collection. MASSCOMP subroutines required to set-up a data transfer differ slightly between parallel and analog modes. For both types of data acquisition modes, simple opening 'mropen' (21:Ref-79) and closing 'mrclose' (21:Ref-34) routines initialize and close a data transfer. However complete device initialization is simpler for the parallel than the analog mode.

Complete parallel device set-up requires only using 'mrpdmod' to identify a data mask used to trigger the beginning of actual data transfer. This way, the parallel device will not enable data collection until incoming data

Start Data Collection. This user selection tells Cllctdata to start the data collection by executing three subroutines in turn; Initgraphics, Initda, and Collectdata. Initgraphics controls the initialization of the graphics processor, display window and display segments. Initda initializes the MASSCOMP data acquisition. The Collectdata subroutine controls the acutal collection.

Initgraphics. Initializing the graphics processor means executing 'mgiasngp' (20:2-3), a graphics subroutine designed to direct the host processor to "assign" the graphics processor and initialize the graphics subsystem. DAADS routine Initgraphics does this and then creates one display window (20:1-8,1-12) for each input channel up to a display maximum of 12. Although MASSCOMP allows up to 16 graphics display windows, windows 0 and 1 are reserved for system use, window 2 is left intact establishing a boundry reference for other windows and one window is left unused. Each display window contains a labeled coordinate system representing either a bipolar voltage range (+5v and -5v) for analog inputs or a unipolar (0v to 10v) range for digitized parallel input.

Internal to Initgraphics, routine Initchanorder initializes the channel labels by reading a user supplied channel order file. This file tells DAADS the labels to use and the order of channel input. The coordinate system can not be labeled without the channel order file, therefore

previous session, perform analysis on stored data or exit the system. A valid response must be given before exiting the menu loop.

Cllctdata. the Cllctdata module drives the data acquisition, display and store function of DAADS. A menu allows the user to set-up for data collection, start the data collection or exit back to the main menu. The sturcture of Cllctdata is shown in Appendix D, pages D-21 to D-23.

Set-up. Set-up, whether from a file or from the keyboard, refers to the DAADS getting information for the data collection session. Needed information includes session name, output file name, number of channels to collect, number of channels to display, name of the channel order file and finally the collection mode; parallel or analog. One of two internal subroutines, read_setup and interactive_setup, get the set-up information.

Read_setup reads from an existing user-supplied disk file all the information stated above. This file must be in the format shown in Appendix F. Interactive_setup allows the user to supply the information through the keyboard. This information, either read in from a disk file or from the keyboard, is written to a Session Header file created under a user supplied name. The Session Header file contains the information for later input to the Replay function of DAADS. All information must be supplied before starting the data collection.

MASSCOMP software developed provides this data collection capability.

System Analysis and Design Techniques (SADT). The SADT diagrams in Appendix D graphically describes the AFIT BDAS requirements for the MASSCOMP. A Data Acquisition and Display System (DAADS) satisfies the dual SAM and AFIT requirements of analog and parallel inputs. Appendix E contains the SADT diagrams for the Programmable Digtal Collection Software (PDCS) for the BDAS on-board PDCE. Together the DAADS and the PDCS form the system software needed to collect biophysical data for motion sickness studies at AFIT.

DAADS Software Design

The DAADS software design for the BDAS was developed from the SADT diagrams. Structure charts in Appendix D, created from the SADT diagrams, show module relationships and identify the modules by their "as coded" names.

The main DAADS module, Daadsmnu, presents the user a choice of functions. The user response determines the function desired and causes a branch to either Cllctdata, Extract, Replay, or Perform Data Analysis.

Daadsmnu. Daadsmnu presents the DAADS main menu. From this menu the user decides to collect and display data, extract a channel from a exixting binary file, replay a

2. the system software shall acquire and store data for later off-line analysis or display;

3. the system shall collect, store and display the data on a real-time basis. Real-time is defined as a short as possible time-span for operator usable data presentation;

4. the system shall collect and store up to 16 channels of data;

5. displayed data shall be clearly identified on the screen to avoid confusion when displaying several channels from different data sources;

Additional system requirements for the AFIT BDAS system for the MASSCOMP and on-board PDCE include:

1. MASSCOMP software shall work for both analog and parallel inputs. This requirement allows both concurrent and follow-on thesis efforts to use MASSCOMP data collection and display capabilities;

2. after data collection, the MASSCOMP software shall provide off-line means to isolate a single data channel into a file for later analysis;

3. software controlling the chair PDCE shall be menu driven;

4. the PDCE software shall allow the operator to select the sampling rate and channels to be digitized;

5. testing the SICM interface to insure the integrity of the data received by the MAC;

6. monitoring the data channels from the remote terminal display to verify transducer integrity independent of the MAC and SICM;

7. providing a user help guide;

8. entering the resident CIM Monitor program from the system program;

These additional requirements for the AFIT BDAS provide system flexibility and adapatability for possible future requirements and experimental procedures. In this project the

4 - 2

IV. System Software

This chapter identifies the system software require-
ments for the MASSCOMP computer and the chair on-board
Programmable Digital Collection Equipment. Also, a brief
description of each coded module presents an overview of
modular functions. System Analysis and Design Techniques
(SADT) diagrams were used to refine the requirements. These
diagrams and resulting "as implemented" structure charts are
in appendices D and E.

System Software Requirements

Overall, the system software requirements are divided
into two separate versions. Both versions, one for School
of Aerospace Medicine (SAM) and the second for the AFIT
Biophysical Data Acquisition System (BDAS), extensively use
the MASSCOMP. However, the AFIT version additionaly con-
tains software for the PDCE portion of the BDAS. Also, the
Brooks AFB version receives biophysical data in analog form
while the AFIT version inputs the biophysical data already
digitized into a parallel signal.

For either version, the system must collect, store and
display biophysical data regardless of its origin. Research
into both versions produced the following common
requirements:

1.   the system software shall be menu driven. This
     allows use of the system without extensive
     programming or computer science background;

4 - 1

bit output ports of the PDCE Parallel I/O circuit.

To detect an interface error, the MAC must input each 16 bit word from the PDCE and determine if the upper and lower 8 bit patterns are equal. If they are, the MAC should also determine if the 8 bit pattern is an increment larger than the previous pattern. A failure of either tests indicate an error exists in the interface. Due to the presence of an antideadlock ciruit in the SICM, the first data word should always be discarded before checking the data stream.

Dspacq. The Dspacq module provides the user with the capability to monitor all 16 channels at a fixed sample rate without using the MAC. This capability is particularly useful in pre-collection setup of the transducer channels and in diagnosing malfunctions as it eliminates the complexity and uncertainty of the MAC element in the system debugging. Dspacq allows the user to select the display format, either in tabular form (<L>ist) consisting of 16 columns, one for each channel, or as a 16 row pseudo-bar graph (<P>lot).

<L>ist. <L>ist sequentially samples each of the 16 channels and displays them in tabular form, channel 0 in the leftmost corner of the screen through channel 16 in the rightmost corner. New data enter from the bottom of the screen while old data leave through the top. The data for each channel is displayed as 5 hexidecimal characters. The leftmost character is the 4 bit channel ID followed by 3 hex

characters representing the 12 bit channel ID. The data are terminated by a space to properly space the columns to fit inside the 80 column display.   Dspacq allows the user to stop and start the display using the space bar.   To exit <L>ist and return to MAIN, the user presses e<X>it while <L>ist is stopped.

<L>ist samples all 16 channels sequentially at a fixed rate of approximately 167 channels per second or about 10 samples per channel per second. <L>ist is the faster of the two Dspacq sub-modules.

<P>lot.   <P>lot allows the user to monitor all 16 channels at a slower fixed rate of about 80 channels per second or about 5 samples per channel per second.   The advantage of <P>lot is that it places data for each channel on the screen relative to the channel ID and the data value.

Channel 0 is displayed at the top row of the screen and the appropriate column proportional to the data while channel 15 is displayed on the 16th row. For example, given that there are 16 channels, an 80 column remote terminal display, and data values from hexadecimal 000 to FFF, the four character data value 'A800' representing an ADC result, 800, for channel 10, A, would be displayed beginning at row 11, column 40.

Data were chosen to be displayed rather than true bar-graphs because of the processing limitations of the remote terminal.   Like <L>ist, <P>lot can also be temporarily

halted for viewing data.

Hlpmsg. The Hlpmsg module generates a one screen re-fresher on the function of each Menu option. This function is basic and will become less used as the user becomes familiar with the PDCS.

V. Experiment Procedures

The function of the Biophysical Data Acquisition System (BDAS) is to collect and analyze biophysical subject data. The collection and analysis procedure consists of the following steps:

1. power-up the BDAS;

2. adjust and calibrate the analog-to-digital converter (ADC) circuit;

3. set-up and verify operation of the biophysical data acquisition tranducers attached to the subject;

4. using a MAC utility program, verify the chair-MAC interface;

5. start-up the DAADS to conduct the experiment; and finally

6. power-down the system at the end of a collection.

BDAS Power-Up

There are four major subsystems which must be cabled up and powered-on before data collection can begin. They are the MAC, SICM, Remote Station, and Chair.

The power-on sequence is not crucial; however, all subsystems must be powered-on before the system can operate. A suggested sequence is to first turn on the MAC terminals and chassis followed by the SICM, the Remote Experimenter Station console and terminal, and the chair equipment. Power-on of the chair involves PDCE, PME, and the Autogen equipment.

ADC Adjustment and Calibration

Before each experiment, the PDCE ADC circuit should be adjusted and calibrated as necessary for the specific data characteristics to be encountered. The details are found in the National Semiconductors CIM-411 manual (3) but in general cover such areas as signal baseline, gain, polarity, and range. Appendix B contains a description of the current circuit settings.

Transducer Setup and Operation Verification

Sequence. Attach the transducers in the following sequence for ease of placement:

1. Electrocardiogram (ECG)
2. Electrogastrogram (EGG)
3. Electrointestinogram (EIG)
4. Electronystagnogram (ENG)
5. Facial photo-plethysmograph
6. Chest pneumograph
7. Waist pneumograph
8. Galvanic skin response potential (GSRP)
9. Myograph
10. Finger photo-plethysmograph
11. Galvanic skin response conductance (GSRC)
12. Thermometer

After attaching all the transducers, assist the subject into the chair and connect all the transducers to their

appropriate monitoring equipment. Turn on the Autogen and PME and allow a two minute warm up period for the decay of the PME system's initial transient responses.

Placement and Alignment. For the placement of the ECG, EGG, EIG, ENG, and facial photo-plethysmograph refer to figure 5.1. The placement of the pneumographs should allow full compression upon the subject's exhaling and expansion starting at the beginning of the subject's inhaling. The alignment for the Physiological Monitoring Equipment (PME) is discussed in Earl and Peterson's thesis (9: Appendix B) and will not be discussed in this study. The alignment procedures for the EIG and ENG are the same as for the ECG and EGG. The placement and alignment of the Autogen Corporation transducers are found in the equipment's Instruction Manuals (13, 14, 15, 16) and will not be discussed in this study.

Verification. Once the transducers are attached and connected, the operation of the transducers and the ADC circuit can be verified from the Remote Station terminal. Specifically, the user enters the Programmable Digital Collection Software (PDCS) from the CIM Monitor program by executing the Monitor command line "GF000" which begins the PDCS collection program found at hexidecimal address F000.

By selecting the Main Menu's Display function, the user may view the tranducers and ADC circuit outputs either in a list or plot format to verify proper setup and operation.
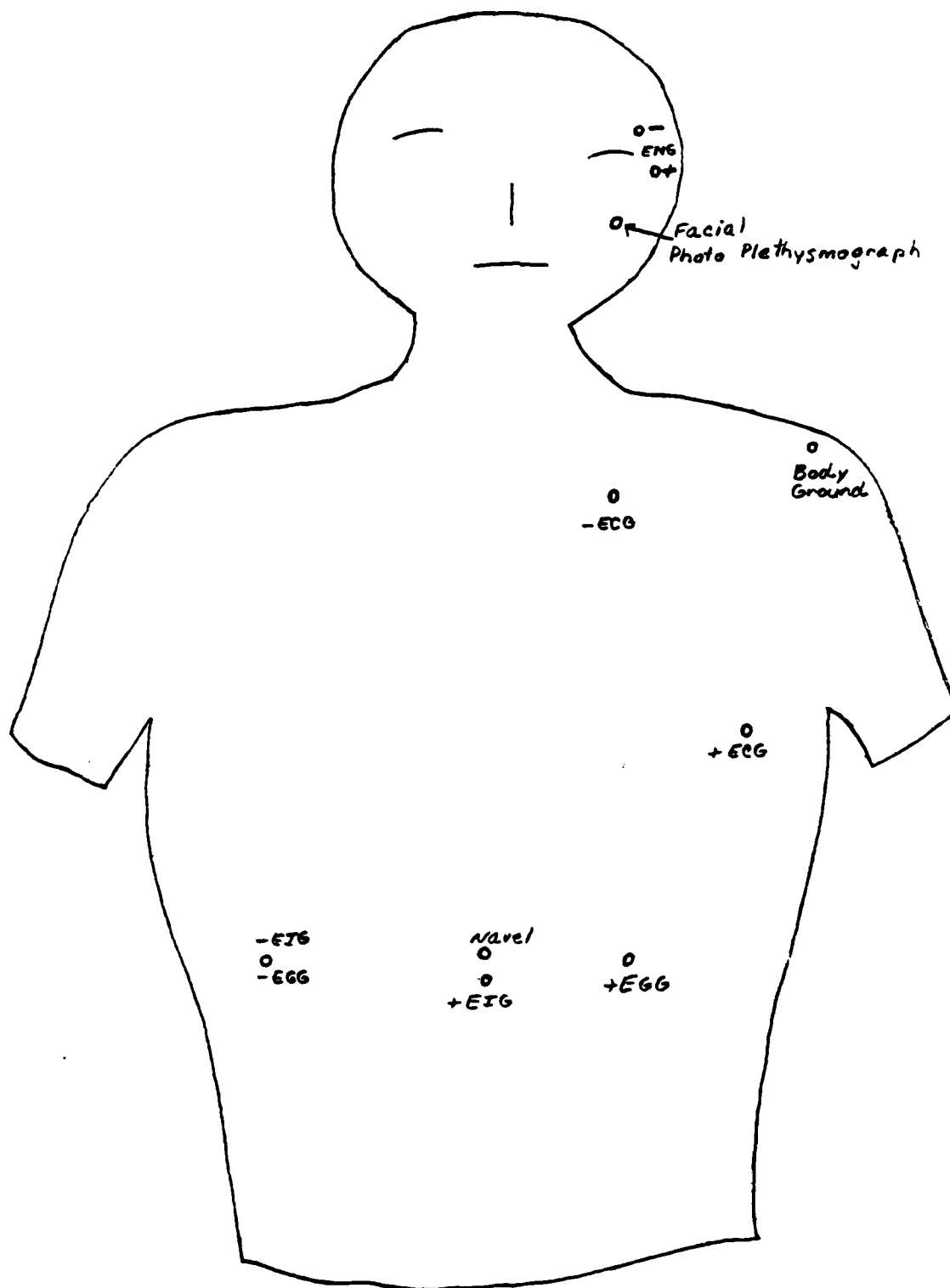
Figure 5.1 Physiological Electrode Placement

Operational Chair-MAC Interface Verification

Once the transducers are attached and operationally verified, the user should verify the operational integrity of the interface between the chair and the MAC. Failure to verify the integrity of the transducers, ADC circuit, and the interface before beginning a collection could result in a collection of data which can not be properly analysed either due to improper transducer attachment, faulty transducer operation, faulty ADC circuit, or data corrupting interface.

Verification is accomplised by selecting Main Menu's "Test" function which generates and transmits 16 bit test patterns through the PDCS parallel I/O circuit, sliprings, and SICM to the MAC. A MAC utility program, "Bitest.x", inputs the data and displays it. Discrepancies in the test patterns received reflect possible faults in the I/O circuit, sliprings, SICM, or MAC's internal interface ciruits.

Experiment Process

Having verified the ADC circuit transducers, and chair-MAC interface, the experiment can begin. To start, the MAC DAADS is activated, collection parameters selected, and the data acquisition started (appendix G outlines the DAADS operational procedures). During data acquisition, the user may choose to display a selected number of data channels and/or store selected data channels on magnetic

memory disks.

To analyze the data, the data acquisition must first be terminated before retrieving data from disk.

CAUTION: Disconnect all transducers after completing a data acquisition experiment to prevent damaging them. Assist the subject out of the chair as the subjects sense of balence may initially be unstable.

System Power-Down

Once an experiment is completed the system should be powered down, especially those system components that are battery powered.

The power-down sequence is not crucial; however, a suggested sequence would be to turn off the Remote Experimenter Station, then the battery-powered chair equipment, and finally, the SICM. The MAC system is left on unless the system will be moved or left unactended for an extended period of time.

VI. Conclusions and Recommendations

The basic thesis effort was to continue the development
of a computerized biophysical data acquisition system (BDAS)
started by Capts Earl and Peterson (9). The following are
our conclusions and recommendations.

Conclusions

The computerized biophysical data acquisition system
built in this thesis effort provides the basic too' for a
comprehsive study of motion sickness incidence (MSI). By
successfully integrating a MASSCOMP MC500 computer and add-
ing the EIG and ENG transducers, a powerful real-time acqui-
sition and analysis capability now exists for capturing and
studying the predictive MSI interrelationships of up to 12
biophysical parameters. The addition of a 166 mbyte hard
disk provides for rapid storage and retrieval of these
parameters via biophysical data bases.

Recommendations

Although the basic design and development of the inte-
grated Biophysical Data Acquisition System (BDAS) is com-
plete, further system enhancements or additions are recom-
mended; particularly concerning the design of the trans-
ducers, MAC data analysis software, and PDCE data sampling
process.

Transducer Design. Currently, each biophysical parameter needs its own transducer which must be carefully attached to the subject. Integrating some of these transducers into single units would speed the process for attaching transducers.

For instance, commercially available photo-plethysmographs exist which provide information on blood flow changes and heart rate. Also, by using a glove, the temperature transducer and the two dermograph transducers can be integrated into a single unit which would also free one of the subject's hands for easier control of the subject's input transducer. In addition, replacing the presently bulky pneumograph transducers with smaller strain guage type pneumographs would further streamline the transducers.

MAC Data Analysis. With only the basic BDAS system design complete and functional, additional software must be developed to analyze biophysical data bases for the existence of predictive relationships concerning motion sickness incidence.

A suggested approach is to:

1. develop precisely defined and repeatable experimental procedures,

2. collect, store, and retrieve biophysical data,

3. research current multivariate analysis techniques and determine the applicability and limitations of each for use in a data base search for predictive MSI relationships,

4.   develop a flexible MAC analysis program which
     allows the user to manipulate data bases in search
     of predictive relationships, and finally,

5.   evaluate the analysis results and determine the
     most reliable experimental procedure(s) and analy-
     sis technique(s) for predicting MSI.

Several general analysis techniques which should be
considered in searching for predictive relations in
collected data are to:

1.   evaluate time variations in statistical parameters
     such as means and standard deviations of data
     samples against previously defined baseline values,

2.   evaluate variations in statistical relationships
     using auto, cross, or partial correlation tech-
     niques against baseline values,

3.   evaluate changes in moving averages, instantaneous
     magnitude differences, and their histogram distri-
     butions against baselines,

4.   search for obscure nonlinear interrelationships
     via scatter plots, and finally,

5.   evaluate changes in the frequency spectrum via
     spectral analysis techniques.

PDCE Enhancements. The Programmable Digital Collection
Software (PDCS) currently implements the selection and main-
tenance of sample rates entirely in software. A fixed
number of sample rates are possible only by avoiding exten-
sive data processing and decision analysis while sampling
the data.

An interrupt driven version of the current PDCS would
improve its data processing capabilities but would require
the development of a PDCE sample rate circuit.

Appendix A

This appendix discusses the relevance, biomedical con-
siderations, and electrical schematics and characteristics
of the Physiological Monitoring Equipment (PME).

Electrocardiogram (ECG)

The electrical activity of the heart, a well known
motion sickness variable, is measured by the electrocardio-
gram (ECG) trandsducer. The frequency response ^f the fab-
ricated transducer is from .05 Hz to 10 Hz. The electrical
schematic for the ECG is shown in figure A.1.

Electrogastrogram (EGG)

Electrical activity of the stomach, a function of its
contractile state, is measured by the electrogastrogram
(EGG). The stomach is well known to become atonic with the
experience of nausea, while during retching the distal stom-
ach contracts and the proximal stomach relaxes (25). The
electrode used is a peri-umbilical application and has a
frequency response of from .01 Hz to .12 Hz. This is well
within the range of the stomach's general mixing contrac-
tions of from .016 Hz to .05 Hz (12). The electrical sche-
matic for this transducer is shown in figure A.2.

Electrointestinogram (EIG)

The electrointestinogram (EIG) measures the electrical
activity of the small intestine. The duodenum is well known
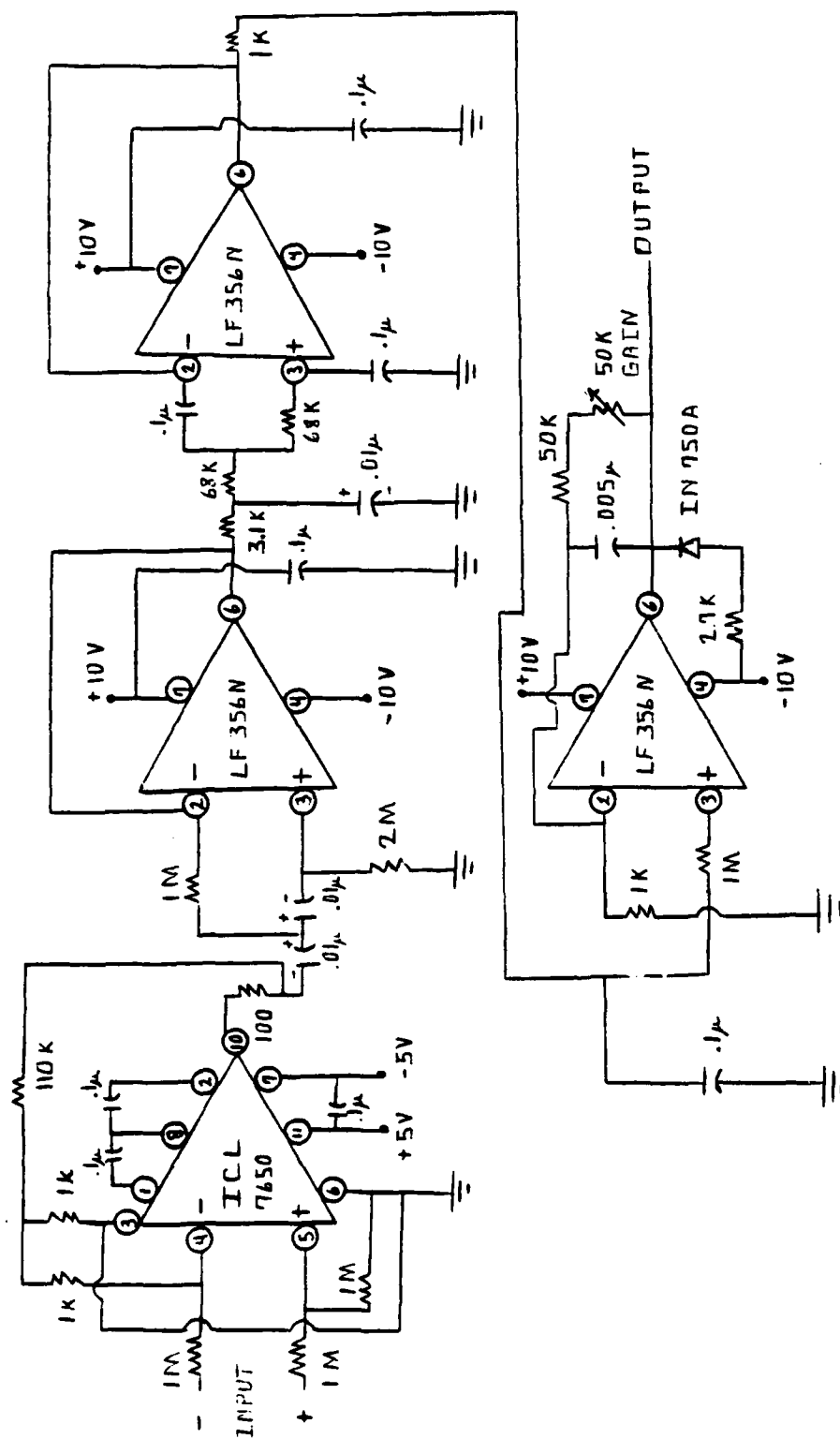
Figure A.1 ECG Schematic

Appendix C

This appendix contains a SICM parts list, IC layout diagram, and wiring list.

Parts List

Location	Device	Function
U1	MC1489	Quad Line Receiver
U2	MC1489	Quad Line Receiver
U3	MC1489	Quad Line Receiver
U4	MC1489	Quad Line Receiver
U5	MC1489	Quad Line Receiver
U6	74280	Parity Generator/Checker
U7	7486	Quad Exclusive-or Gates
U8	74280	Parity Generator/Checker
U9	MC1488	Quad Line Driver
U10	7474	Dual D-type Flipflops
U11	74175	Quad D-type Flipflops
U12	74175	Quad D-type Flipflops
U13	74175	Quad D-type Flipflops
U14	74175	Quad D-type Flipflops
U15	74221	Dual Multivibrators
U16	7474	Dual D-type Flipflops
U17	7432	Quad Or Gates
U18	74221	Dual Multivibrators

```
W10 1-2   closed   internal circuit control signal
W11 1-2   closed   10-20 gain
W12 1-2   closed   10-20 gain
W13 2-3   closed   address line A7=0
W14 2-3   closed   A6=0
W15 2-3   closed   A5=0
W16 2-3   closed   A4=0
W17 2-3   closed   A3=0
W18 2-3   closed   A2=0
```

In addition to these adjustments, the gain and zero can
be adjusted. Precise procedure can be found in the CIM-411
manual.

PDCE Paralled I/O Circuit Layout. The original documentation locating the integrated circuit (IC) devices for the parallel I/O card should be amended to reflect the actual layout (9).

The IC location labelled as U18 should be deleted while the IC locations U11 to U17 should be renumbered U12 to U18.

Parity Generator Circuit. The original circuit drawings does not reflect the actual design (9). The parity generator schematic and its associated wiring list should be modified to show the actual connections to be between U14-6 and U13-2 and between U12-6 and U14-4. In addition, U12-4 is tied to the 5 volt line and not to ground as originally documented.

Analog to Digital Converter Adjustments

Before each experiment, the PDCE's ADC circuit should be adjusted and calibrated as necessary for the specific data to be collected. The details of the adjustments can be found in the CIM-411 manual (3); however, for continuity, selected jumper settings and their functions are listed:

Jumper	State	Function
W1	-	set up for 16 non-inverting single-ended channel inputs
W2 2-3	closed	bus request
W3 2-3	closed	bus request
W4 2-3	closed	normal MSB
W5	open	bus request
W6 1-2	closed	bus request
W7 2-3	closed	bipolar
W8 1-2	open	range not divided by two
W9 1-2	closed	20 volt range (-10V to +10V)

original error:
C4 as "seen"
by C1
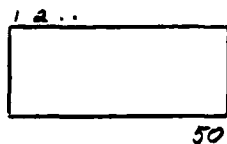
additional error:
C4 as labled on
its connector shell
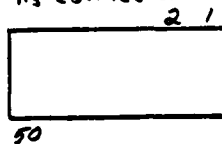
Correction:
actual C4 as CIM-411
Schematics "see it"

a.   C4 Connector

original error:
C19 as documented
by MAC

correction:
C19 as should
be documented
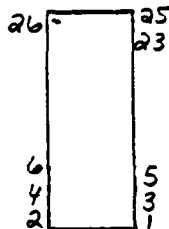
modification:
C19 labelling as
it looks to SICM
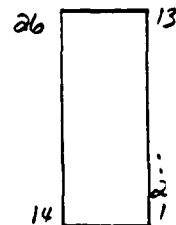
b.   C19 Connector

Figure B.2   Connector Labelling Corrections

Cable connections originally fabricated to route sig-
nals to connectors C4 and C19 followed the aforementioned
labelling convention; however, additional research into the
manufacturer's documentation revealed labelling errors which
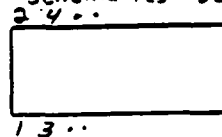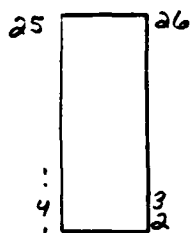in the case of C4 was compounded by the original cable
connection, C1, being improperly fabricated. An ADC adapter
cable (C2-C3) was built to correct the C4 problem while the
original PO, connector C13, was jumpered to create a new PO,
connector C14, to correct the C19 documentation error.
Figure B.2 illustrates these corrections.

A final caution. None of the connectors were found to
be keyed; therefore care must be taken to align pin 1 of
each connector before making the connection to prevent
possible damage to circuit devices.

Documentation Errata. This section overviews the
discovery of documentation errors and corrections crucial to
troubleshooting and maintenance of the signal path.

MAC Digital Interface Port. The pin locations for
the MAC digital interface, as documented in the MASSCOMP
software release notes (22), are incorrect. Figure B.1
illustrate the original and corrected pin locations.

PDCE Analog Interface Port. The pin location for
the CIM-411 input connector do not agree with the actual
connector markings. Figure B.1 reflect the original and
corrected pin location.
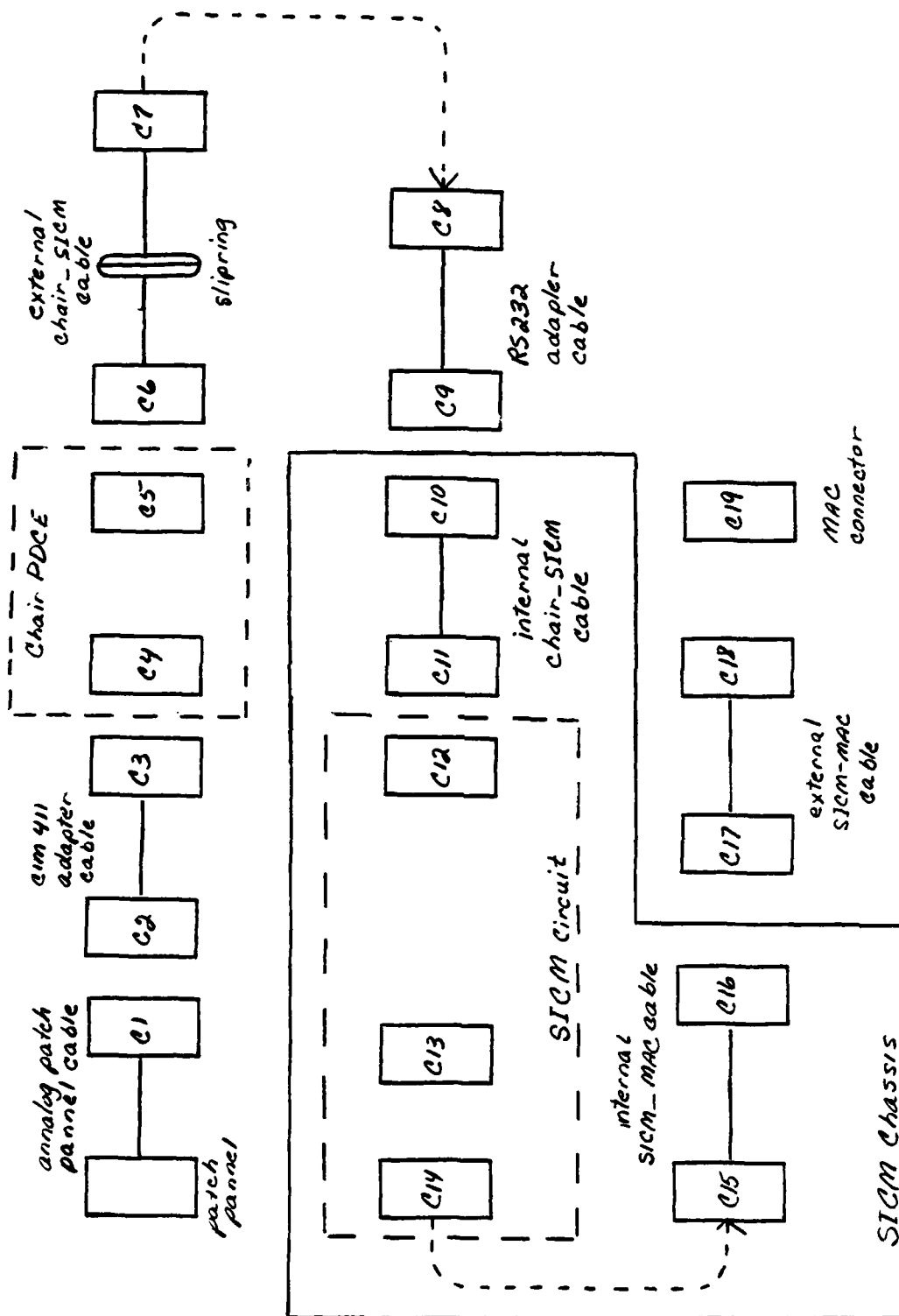
Figure B.1 BDAS Signal Path Diagram

Appendix B

Troubleshooting and Maintenance

As in any complex system, malfunctions will occur. Since much of the Biophysical Data Acquisition System (BDAS) is custom designed, troubleshooting and maintenance will have to be performed in-house since contractor maintenance often will not be available.

This section does not attempt to teach the basics of troubleshooting and maintenance, as the user is assumed to already possess those minimum qualifications. Rather, this section documents the signal path and documentation errata crucial to troubleshooting and maintaining this path. Also included in this section is a listing of selected PDCE CIM-411 settings useful in maintaining the PDCE digitizer.

Signal Path Pin Locations. Figure B.1 illustrates the path which data take from the analog patch panel inputs to the final destination, the MAC parallel input connector. This path contains 19 connectors, six cables, two circuits, and one jumpered connector pair (C13 and C14).

By convention, pin 1 of every double row connector is designated by an indentation on the connector shell's exterior, usually triangular. The remaining connector pins are numbered up from pin 1 and ,when the end of the row is reached, continues at the first pin across from pin 1. With two exceptions (C4 and C19), this convention is followed throughout the entire signal path.

Figure A.6 Photo-Plethysmograph Schematic

A - 9
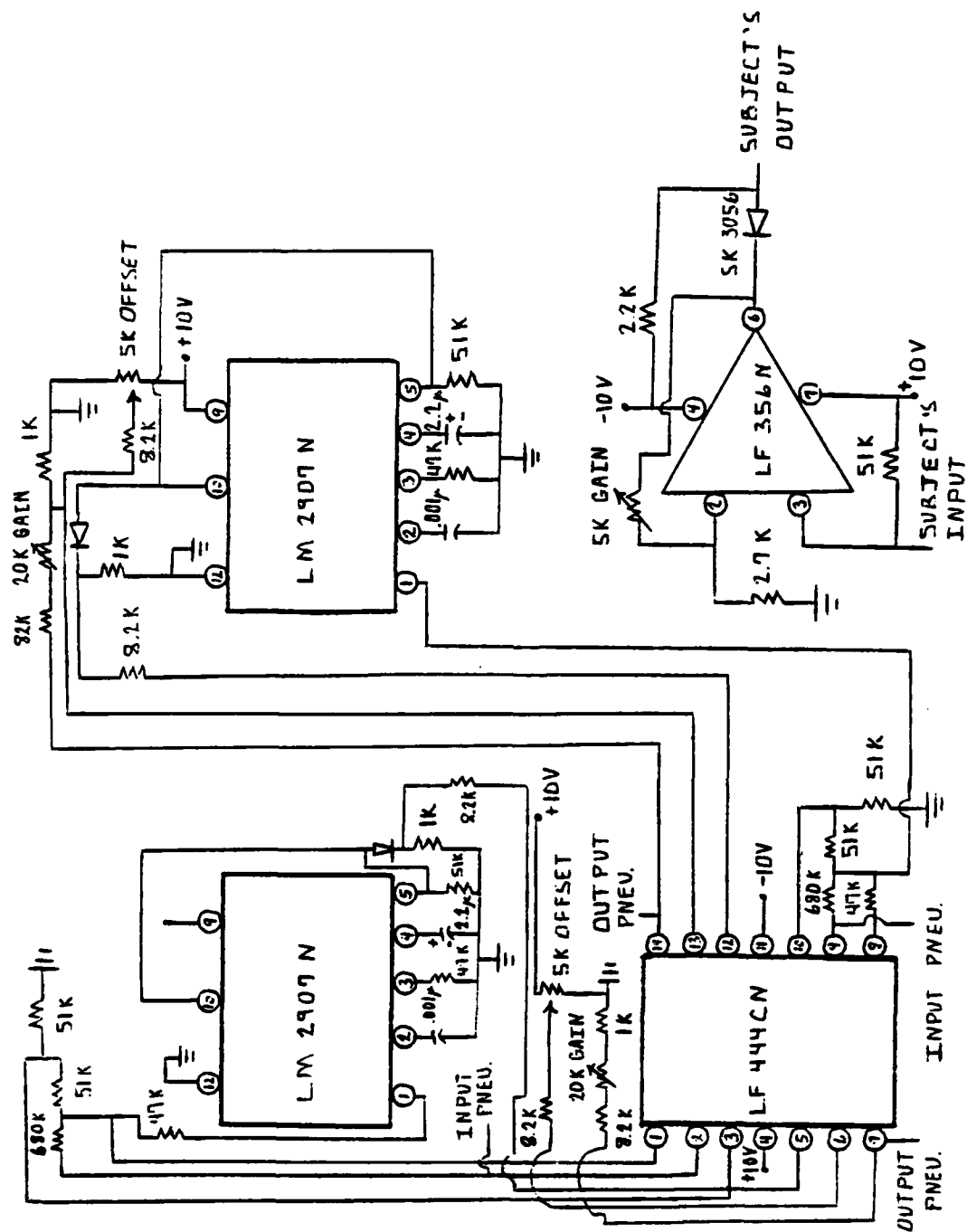
Figure A.5 Pneumograph Schematic

Pneumographs

The rate and depth of the subject's respiration is measured by two pneumographs. The pneumographs measure chest and abdominal breathing since one symptom of motion sickness is the shift of breathing between these two areas. The frequency response of the two pneumographs is from D.C. to 2 Hz. Both pneumograph's circuits are identical and are on the same circuit board along with the subject's input circuit. The electrical schematic for this board is shown in figure A.5.

Photo-Plethysmographs

The change in blood flow to the face and a finger is measured by two photo-plethysmographs. The change in skin pallor is an easily observed symptom of motion sickness. The frequency response of the facial and finger photo-plethysmographs are from .25 Hz to 5 Hz. Both the facial and finger photo-plethysmographs' circuits are identical and are on the same circuit card. The electrical schematic for one photo-plethysmograph is shown in figure A.6.

A functional description of the design and key components of the pneumographs and photo-plethysmographs are discussed in Earl and Peterson's thesis (9: Chapter 3, Appendix A).
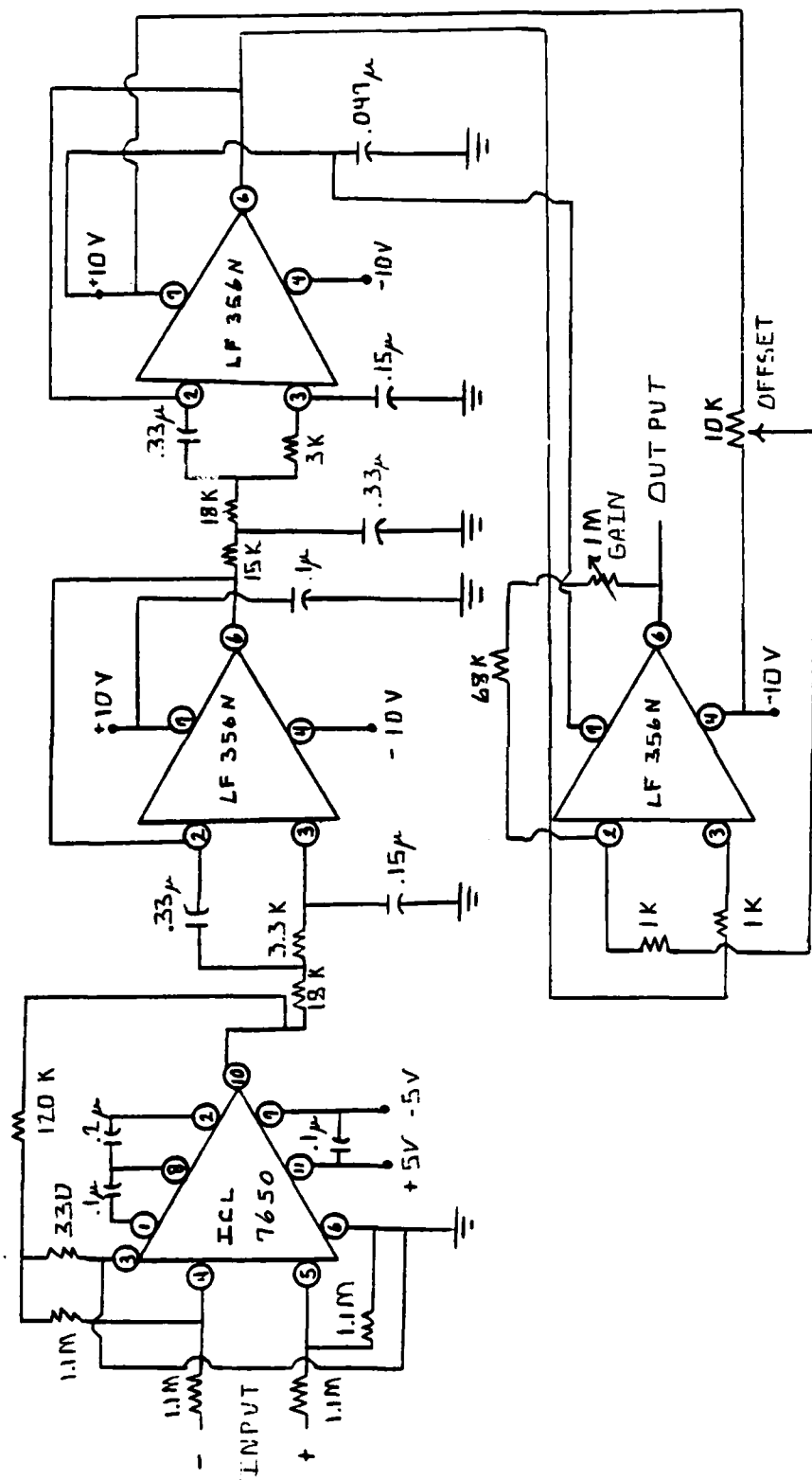
Figure A.4 ENG Schematic

A - 6
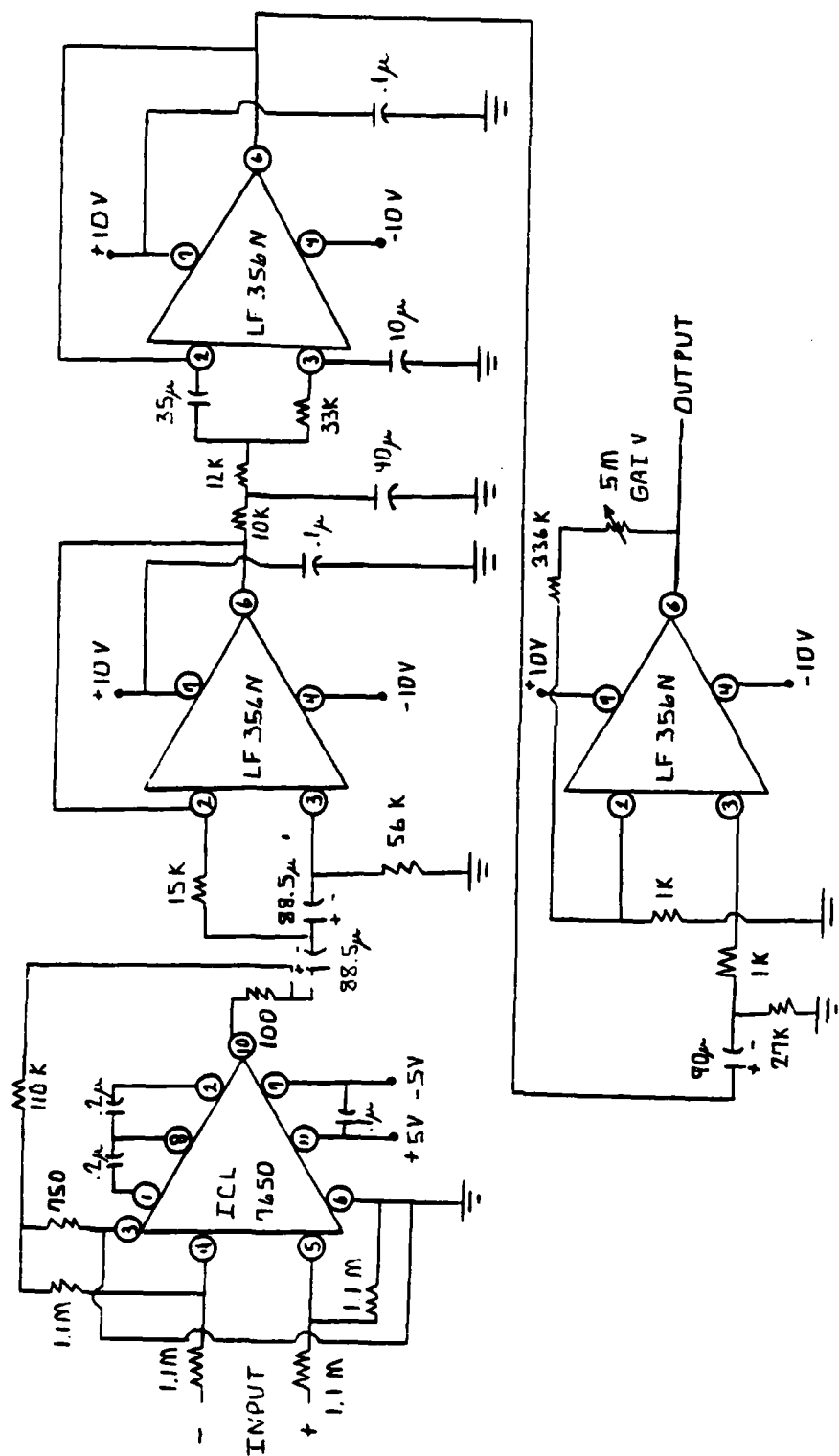
Figure A.3 EIG Schematic

A - 5

to increase its activity with the onset of nausea (25). The frequency respnse of the transducer is from .06 Hz to .24 Hz which covers the basic frequency of the small intestine of .2 Hz (12). The electrical schematic for the EIG is shown in figure A.3.

Electronystagmogram (ENG)

The electronystagmogram (ENG) monitors the ocular movement by measuring the change in the potential seen across the eye. Electrodes placed lateral to the eye will measure a rightward glance as a right to left positive potential proportional to the magnitude of the rightward glance and a similar potential to a vertical glance if electrodes are placed over the eye. The electrical activity of the eye is a well documented motion sickness variable (8, 10, 23). The frequency response of the fabricated ENG is from .1 Hz to 30 Hz. The electrical schematic of this transducer is shown in figure A.4.

All of the electrical schematics for the ECG, EGG, and the newly developed EIG and ENG are of the same basic design with a few variations. The reasons for developing this basic design, the safety precautions considered, and the functional description of each component of this basic design are discussed in Earl and Peterson's thesis (9: Chapter 3, Appendix A).

Figure A.2 ECG Schematic

A - 3
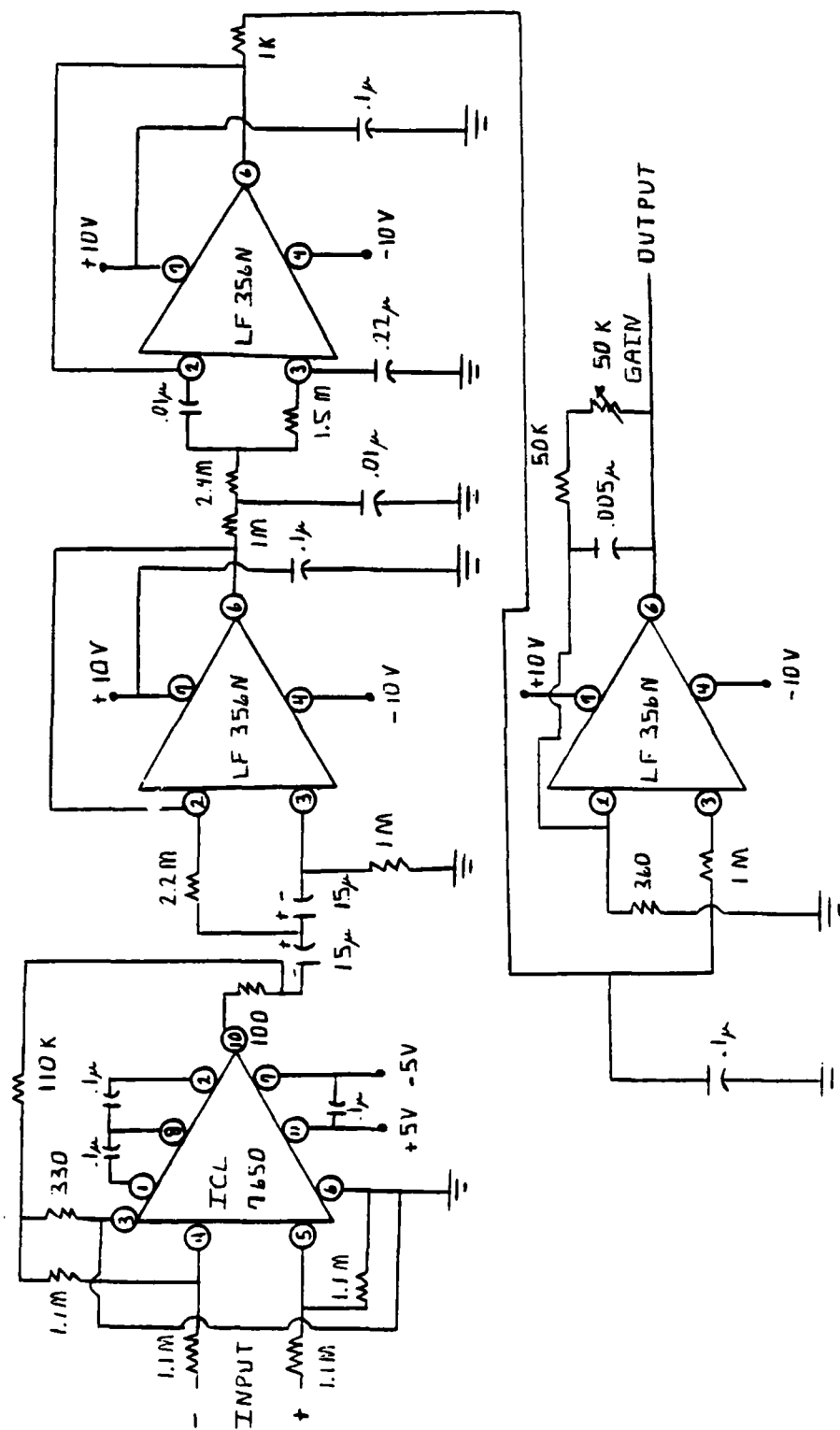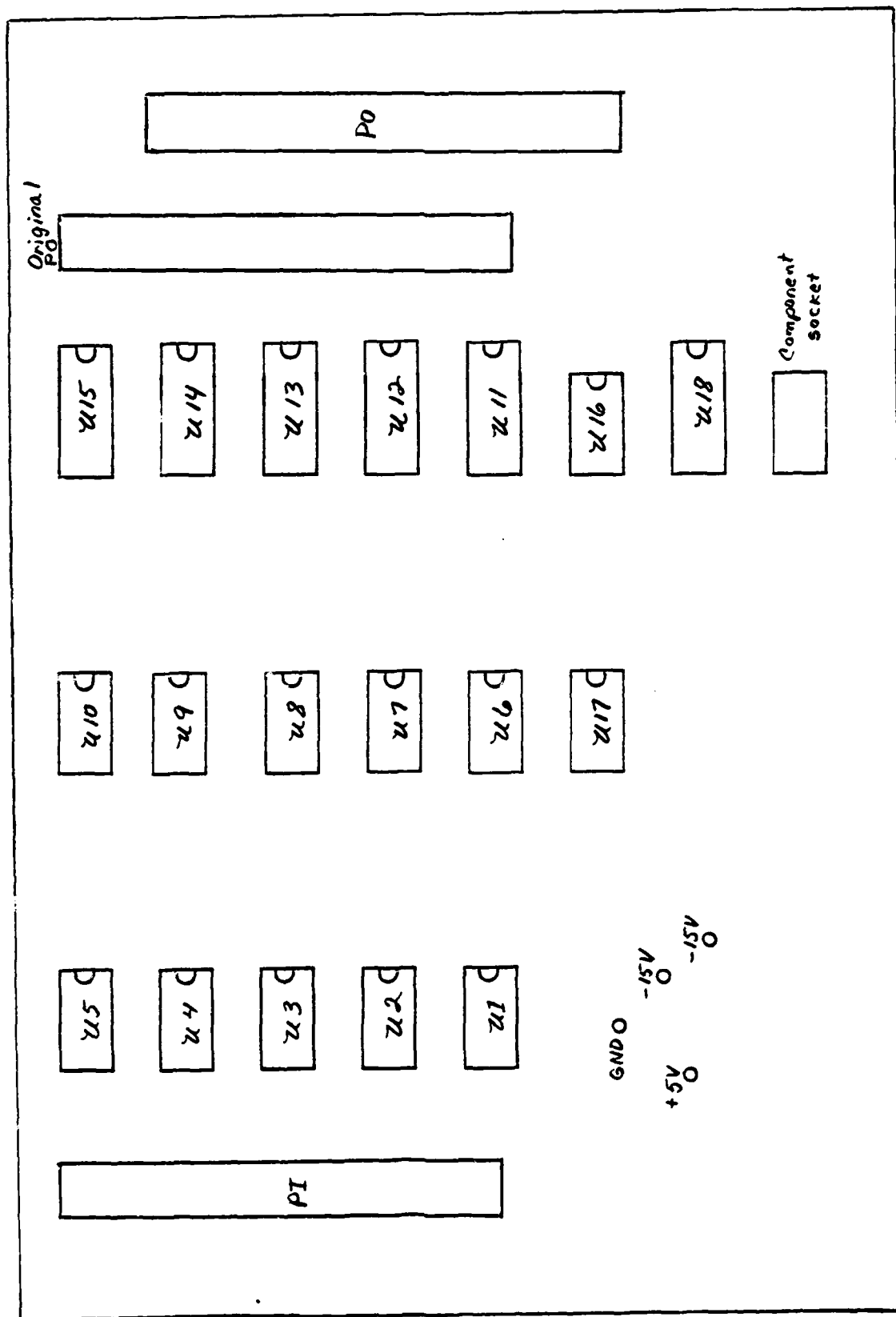
Figure C.1 SICM IC Layout

Wiring List

ID: U1 - MC1489 Quad Line Receiver

FROM	TO	SIGNAL DESCRIPTION
1.	PI-20	*PA4 ("*" means active-low)
2.	-	
3.	U11-4 U6-13	PA4
4.	PI-21	*PA5
5.	-	
6.	U11-5 U6-12	PA5
7.	GROUND	
8.	U11-13 U6-2	PA2
9.	-	
10.	PI-18	*PA2
11.	U11-12 U6-1	PA3
12.	-	
13.	PI-19	*PA3
14.	+5 VOLTS	

ID: U2 - MC1489 Quad Line Receiver

FROM	TO		SIGNAL DESCRIPTION
1.	PI-22		*PA6
2.	-		
3.	U12-4	U6-11	PA6
4.	PI-23		*PA7
5.	-		
6.	U12-5	U6-10	PA7
7.	GROUND		
8.	U12-13	U6-4	PA0
9.	-		
10.	PI-16		*PA0
11.	U12-12	U6-8	PA1
12.	-		
13.	PI-17		*PA1
14.	+5 VOLTS		

ID: U3 - MC1489 Quad Line Receiver

FROM	TO	SIGNAL DESCRIPTION
1.	PI-10	*PB7
2.	-	
3.	U13-4 U8-11	PB7
4.	PI-9	*PB6
5.	-	
6.	U13-5 U8-10	PB6
7.	GROUND	
8.	U13-13 U8-13	PB5
9.	-	
10.	PI-8	*PB5
11.	U13-12 U8-12	PB4
12.	-	
13.	PI-7	*PB4
14.	+5 VOLTS	

```
ID:  U4 - MC1489 Quad Line Receivers

FROM        TO                  SIGNAL DESCRIPTION
------      ------              --------------------------------

1.          PI-4                *PB1

2.          -

3.          U14-4   U8-9        PB1

4.          PI-3                *PB0

5.          -

6.          U14-5   U8-8        PB0

7.          GROUND

8.          U14-13  U8-2        PB3

9.          -

10.         PI-6                *PB3

11.         U14-12  U8-1        PB2

12.         -

13.         PI-5                *PB2

14.         +5 VOLTS
```

ID: U5 - MC1489 Quad Line Receivers

FROM	TO	SIGNAL DESCRIPTION
1.	PI-11	*H1
2.	-	
3.	U15-2	H1
4.	PI-12	*PARITY
5.	-	
6.	U7-1	PARITY
7.	GROUND	
8.	-	
9.	-	
10.	-	
11.	-	
12.	-	
13.	-	
14.	+5 VOLTS	

ID: U6 - 74280 Parity Generator/Checker

FROM	TO	SIGNAL DESCRIPTION
1.	U1-11	PA3
2.	U1-8	PA2
3.	-	
4.	U8-6	PARITY
5.	-	
6.	U7-2	T-PARITY
7.	GROUND	
8.	U2-11	PA1
9.	U2-8	PA0
10.	U2-6	PA7
11.	U2-3	PA6
12.	U1-6	PA5
13.	U1-3	PA4
14.	+5 VOLTS	

ID: U7 - 7486 Quad Exclusive-or Gates

FROM	TO	SIGNAL DESCRIPTION
1.	U5-6	PARITY
2.	U6-6	T-PARITY
3.	U16-2	PARITY-ERROR
4.	-	
5.	-	
6.	-	
7.	GROUND	
8.	-	
9.	-	
10.	-	
11.	-	
12.	-	
13.	-	
14.	+5 VOLTS	

ID: U8 - 74280 Parity Generator/Checker

FROM	TO	SIGNAL DESCRIPTION
1.	U4-11	PB2
2.	U4-8	PB3
3.	-	
4.	PULLUP RESISTOR	
5.	-	
6.	U6-4	-
7.	GROUND	
8.	U4-6	PB0
9.	U4-3	PB1
10.	U3-6	PB6
11.	U3-3	PB7
12.	U3-11	PB4
13.	U3-8	PB5
14.	+5 VOLTS	

ID: U9 - MC1488 Quad Line Driver

FROM	TO	SIGNAL DESCRIPTION
1.	-15 VOLTS	
2.	U10-9	H2
3.	PI-24	*H2
4.	-	
5.	-	
6.	-	
7.	GROUND	
8.	-	
9.	-	
10.	-	
11.	-	
12.	-	
13.	-	
14.	+15 VOLTS	

ID: U10 - 7474 Dual D-type Flipflops

FROM	TO		SIGNAL DESCRIPTION
1.	U10-2		H1
2.	U10-1	U15-2	H1
3.	U15-4		*STBL_DLY
4.	PULLUP RESISTOR		
5.	U14-9	U10-12	DATA_RDY
6.	PO-11		*STBL
7.	GROUND		
8.	-		
9.	U17-1		IBF_H2
10.	PULLUP RESISTOR		
11.	U15-12		*IBF_DLY
12.	U10-13	U10-5	DATA_RDY
13.	U10-12		DATA_RDY
14.	+5 VOLTS		

ID: U11 - 74175 Quad D-type Flipflops

FROM	TO		SIGNAL DESCRIPTION
1.	U16-5	U12-1	*BAD_DATA
2.	PO-5		IN4
3.	-		
4.	U1-3		PA4
5.	U1-6		PA5
6.	-		
7.	PO-6		IN5
8.	GROUND		
9.	U16-3	U12-9	DATA_RDY
10.	PO-4		IN3
11.	-		
12.	U1-11		PA3
13.	U1-8		PA2
14.	-		
15.	PO-3		IN2
16.	+5 VOLTS		

ID: U12 - 74175 Quad D-type Flipflops

FROM	TO	SIGNAL DESCRIPTION
1.	U14-1	*BAD_DATA
2.	PO-7	IN6
3.	-	
4.	U2-3	PA6
5.	U2-6	PA7
6.	-	
7.	PO-8	IN7
8.	GROUND	
9.	U13-9 U11-9	DATA_RDY
10.	PO-2	IN1
11.	-	
12.	U2-11	PA1
13.	U2-8	PAO
14.	-	
15.	PO-1	INO
16.	+5 VOLTS	

ID: U13 - 74175 Quad D-type Flipflops

FROM	TO	SIGNAL DESCRIPTION
1.	PULLUP RESISTER	
2.	PO-21	INF
3.	-	
4.	U3-3	PB7
5.	U3-6	PB6
6.	-	
7.	PO-20	INE
8.	GROUND	
9.	U12-9 U14-9	DATA_RDY
10.	PO-10	INC
11.	-	
12.	U3-11	PB4
13.	U3-8	PB5
14.	-	
15.	PO-12	IND
16.	+5 VOLTS	

ID: U14 - 74175 Quad D-type Flipflops

FROM	TO	SIGNAL DESCRIPTION
1.	U12-1	*BAD_DATA
2.	PO-4	IN9
3.	-	
4.	U4-3	PB1
5.	U4-6	PB0
6.	-	
7.	PO-2	IN8
8.	GROUND	
9.	U10-5 U13-9	DATA_RDY
10.	PO-16	INA
11.	-	
12.	U4-11	PB2
13.	U4-8	PB3
14.	-	
15.	PO-17	INB
16.	+5 VOLTS	

ID: U15 - 74221 Dual Multivibrators

FROM	TO		SIGNAL DESCRIPTION
1.	GROUND		
2.	U10-2	U5-3	H1
3.	PULLUP RESISTOR		
4.	U10-3		*STBL_DLY
5.	-		
6.	C2		
7.	R2C2		
8.	GROUND		
9.	GROUND		
10.	PO-10		IBF
11.	PULLUP RESISTOR		
12.	U10-11		*IBF_DLY
13.	-		
14.	C1		
15.	R1C1		
16.	+5 VOLTS		

ID: U16 - 7474 Dual D-type Flipflops

FROM	TO	SIGNAL DESCRIPTION
1.	U18-3	H1
2.	U7-3	*PARITY_ERROR
3.	U11-9	DATA_RDY
4.	PULLUP RESISTOR	
5.	-	
6.	U11-1, PULLUP RESISTOR	*BAD_DATA
7	GROUND	
8.	-	
9.	-	
10.	-	
11.	-	
12.	-	
13.	-	
14.	+5 VOLTS	

ID: U17 - 7432 Quad Or Gates

FROM	TO	SIGNAL DESCRIPTION
1.	U10-9	IBFL_H2
2.	U18-5	TMOUT_H2
3.	U9-2	H2
4.	-	
5.	-	
6.	-	
7.	GROUND	
8.	-	
9.	-	
10.	-	
11.	-	
12.	-	
13.	-	
14.	+5 VOLTS	

ID: 18 - 74221 Dual Multivibrators

FROM	TO	SIGNAL DESCRIPTION
1.	GROUND	
2.	U2-8	PAO
3.	U10-2	H1
4.	U18-10	
5.	U17-2	TMOUT_H2
6.	C2	
7	R2/C2	
8.	GROUND	
9.	GROUND	
10.	U18-4	
11.	U18-3	H1
12.	-	
13.	-	
14.	C1	
15.	R1/C1	
16.	+5 VOLTS	

ID: PI (from chair)

FROM	TO	SIGNAL DESCRIPTION
1.	-	
2.	-	
3.	U4-4	*PB0
4.	U4-1	*PB1
5.	U4-13	*PB2
6.	U4-10	*PB3
7.	U3-13	*PB4
8.	U3-10	*PB5
9.	U3-4	*PB6
10.	U3-1	*PB7
11.	U5-1	*H1
12.	U5-4	*PARITY
13.	-	
14.	GROUND	
15.	-	
16.	U2-10	*PA0
17.	U2-13	*PA1
18.	U1-10	*PA2
19.	U1-13	*PA3
20.	U1-1	*PA4
21.	U1-4	*PA5
22.	U2-1	*PA6
23.	U2-4	*PA7
24.	U9-3	*H2

ID: PO (to Masscomp)

FROM	TO	SIGNAL DESCRIPTION
1.	U12-15	IN0
2.	U12-10	IN1
3.	U11-15	IN2
4.	U11-10	IN3
5.	U11-2	IN4
6.	U11-7	IN5
7.	U12-2	IN6
8.	U12-7	IN7
9.	-	
10.	U15-10	IBF
11.	U10-6	*STB
12.	-	
13.	GROUND	
14.	U14-7	IN8
15.	U14-2	IN9
16.	U14-10	INA
17.	U14-15	INB
18.	U13-10	INC
19.	U13-15	IND
20.	U13-7	INE
21.	U13-2	INF
22.	-	
23.	-	
24.	-	

ID: C4 - input connector CIM-411 Analog Input Board

FROM	TO	SIGNAL DESCRIPTION
1.	-	CH0
2.	-	CH1
3.	-	CH2
4.	-	CH3
5.	-	CH5
6.	-	CH6
7.	-	CH7
8.	-	CH8
9.	-	CH9
10.	-	CH10
11.	-	CH11
12.	-	CH12
13.	-	CH13
14.	-	CH14
15.	-	CH15
16.	-	GROUND
17.	-	GROUND
18.	-	GROUND
19.	-	GROUND
20.	-	GROUND

Appendix D

The following Structured Analysis and Design Technique (SADT) diagrams represent a structural refinement of the DAADS requirements. From thses SADT diagrams structure chars were produced. The structure charts presented hare are in "as coded" form; meaning the variable and module names are those used in the source code.

Appendix contents

NODE INDEX

A-0 Data Acquisition and Display System (DAADS).

Abstract: At this level DAADS is seen as a complete system. Inputs and control consist of data acquired from the PDCS produced chair data and user keyboard responses directing DAADS operations. Outputs are data sent to secondary storage and graphics display produced from data collected.

AUTHOR: Cept D.G.Filliard   DATE:
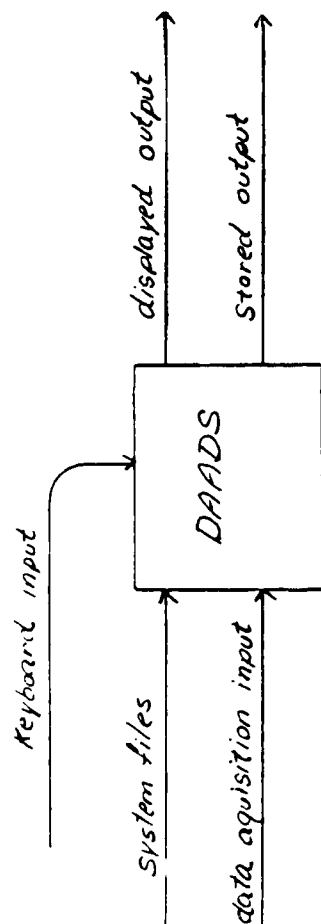
PROJECT: DAADS   REV:

Keyboard input

System files

data aquisition input

DAADS

displayed output

Stored output

NODE: A0   TITLE: DAADS   NUMBER: C1

D - 4

AUTHOR: Capt D.G. Fitzpatrick DATE:

PROJECT: DAADS REV:

daadsmnu
A0

answer

process-
mainrequest
A2

present-
menunu
A1
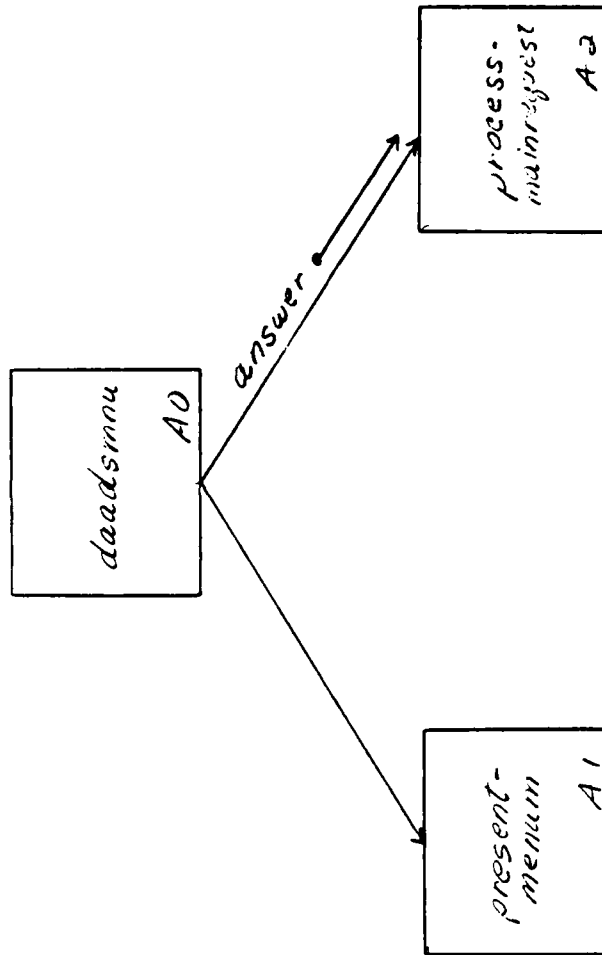
NODE: A0 TITLE: daadsmnu NUMBER:

AUTHOR: Capt D.G. Fitzpatrick   DATE:
PROJECT: DAAVS   REV:

C1 Session identification

Read Session Header File 1

Session header file

nchans, channel order file name

Initialize graphics 2

done

channel order file

data_file name

data_file

Read data file 3

data buffer

Display data 4

all channel display

O1

I1

Session header file, Chan order file, Data file

NODE: A23   TITLE: Replay Session   NUMBER: C7

D - 17

A23 Replay Session

Abstract: The Replay Session module allows the user to
replay off-line, biophysical data previously collected.
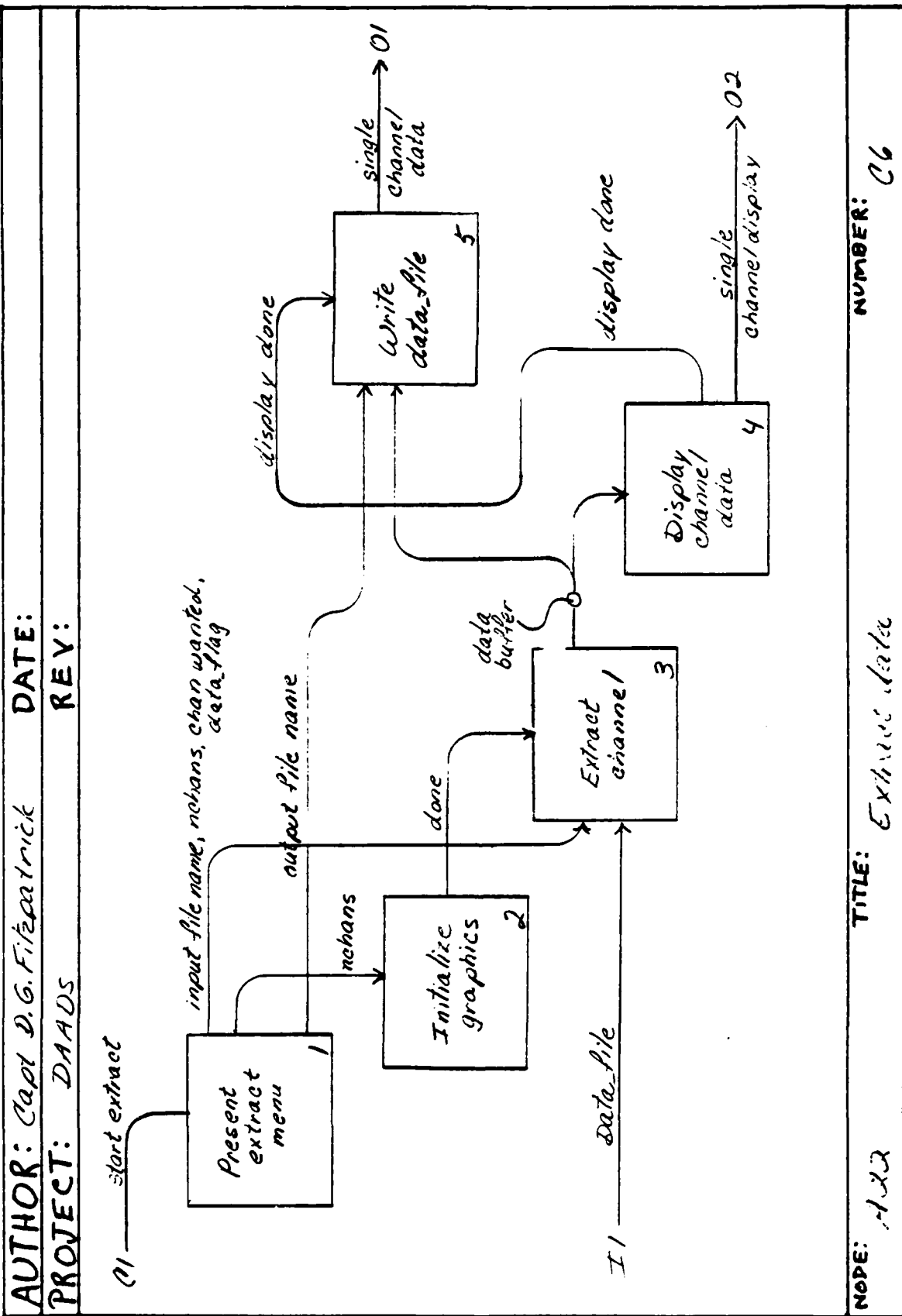This provides an off-line review and analysis of data for
symptomatic and repetitive signals.

A231 Read Session Header File - Asks for session
header file name. Reads the data which includes: the
number of channels collcected, the number of channels dis-
played, the channel labels, the file name of the existing
binary file holding the previously collected data and
finally identifies if the data was originally collected as
analog or parallel.

A232 Initialize Graphics - This routine extensively
uses MASSCOMP graphics routines to initialize the graphics
processor and graphics display. Based on the number of
channels given by the user, graphics display segments are
created. One segment for each channel up to a display
maximum of 12. If more then 12 channels are collected in a
single session, the user is asked to state how many channels
to display. Channels are displayed in sequential order, top
to bottom, left to right. This module also labels each
display based on an input file containing, in order, the
channel labels.

A233 Read Data File - This module reads the data file
into a buffer for access by the display data routine A44.

A234 Display Data - Separates channels, scales data,
and places into individual display buffers. Controls dis-
play buffers to give graphics display the appearence of
motion accross the display window.

single channel data → O1

Write data_file 5

display done

Display channel data 4

single channel display → O2

display done

data buffer

Extract channel 3

Initialize graphics 2

Present extract menu 1

input file name, nchans, chan wanted, data_flag

output file name

nchans

done

(2) start extract

I1 data_file

TITLE: Extract data

NODE: A23   NUMBER: C6

A22 Extract Channel Data

Abstract: The Extract Channel Data module is executed independantly from the rest of DAADS. This module separates from an existing binary multi-channel file a single channel of data. During data collection, channels are stored without separation to reduce the data processing load during real-time operations. Now, for later analysis, the channels can be separated off-line and stored singlurally. This module will cycle so the user can extract several channels without restarting the entire system.

A221   Present   Extract   Questions – This   module   asks operator for the existing binary file name collected from a previous se.ʳion.   Other information asked for includes how many channels are in the multi-channel file, the channel number to be separated, if the data was collected as analog or parallel, display or not the extracted data, and finally the output file name.

A222   Initialize Graphics – Initialized the graphics processor and creates the display grid.   Builds the display segment for graphics processor execution.

A223   Extract Channel – Reads in the data file, separates the wanted channel for either parallel or analog data, then puts data to be written or displayed into a data buffer.   From this buffer both the display module and write module can access the data.

A224   Display Data – Separates channels, scales data, and places into individual display buffers.   Controls display buffers to give graphics display the appearence of motion accross the display window.

A225   Write Data File – Writes the separated data to the user named disk file.

AUTHOR: Capt D.G. Fitzpatrick   DATE:
PROJECT: DAADS   REV:

C1 answer

Perform set_up   1

init data

session header file

Initialize graphics   2

init data

Initialize data aquisition ports   3

F2 channel order file

data buffer

Collect analog data   4

display data

I1 data aquisition input

Collect parallel data   5

stored data

stored data

stored data

display data

data_file

all channels displayed

O1

O2

O3

TITLE: Process dataprequest

NODE: NUMBER: C5

D - 13
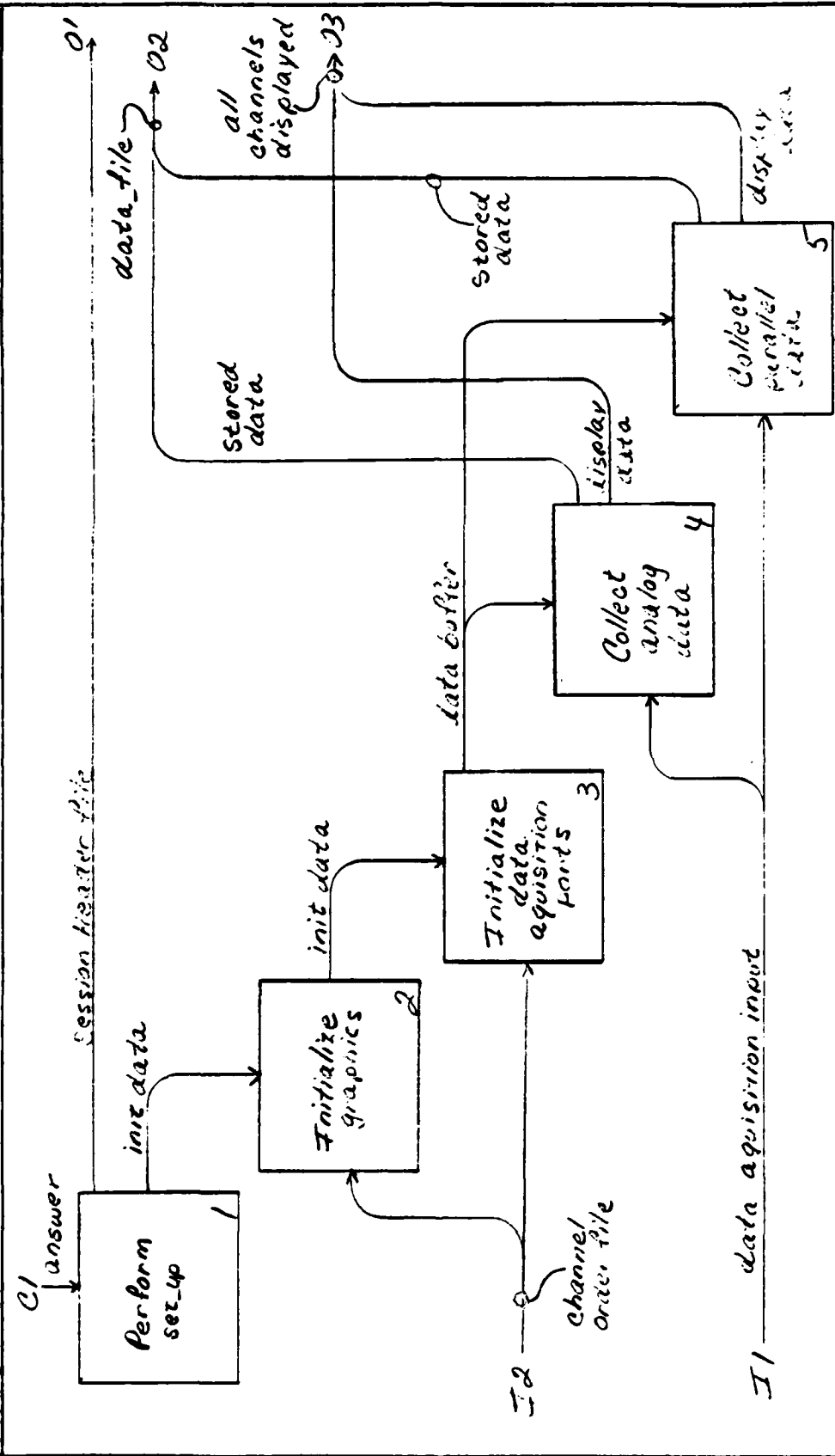
for access by the graphics processor. Performs data
reduction. Based on number of channels per frame, will skip
the same number of frames.   Also separates channels, scales
data, and places into individual display buffers. Controls
display buffers to give graphics display the appearence of
motion accross the display window.

A212 Process dacqrequest.

Abstract: This module determines the function selected by
the user and then branches to the proper routine.   If the
selection is valid, a branch occurs, if not, an error
message is given and the Collect Data & Display menu returns
to the screen.   This happens until the user gives a valid
response.

   A2121 Perform set_up - Does the set-up functions.   Will
ask the user if information needed to run the session comes
from a set-up file or will be entered interactively.   For
doing the set-up from a user given file only the file name
is needed.   Interactive set-up means the user answers ques-
tions to provide the needed information.   One of the⌐ two
methods must be done before furhter data collection proceeds.
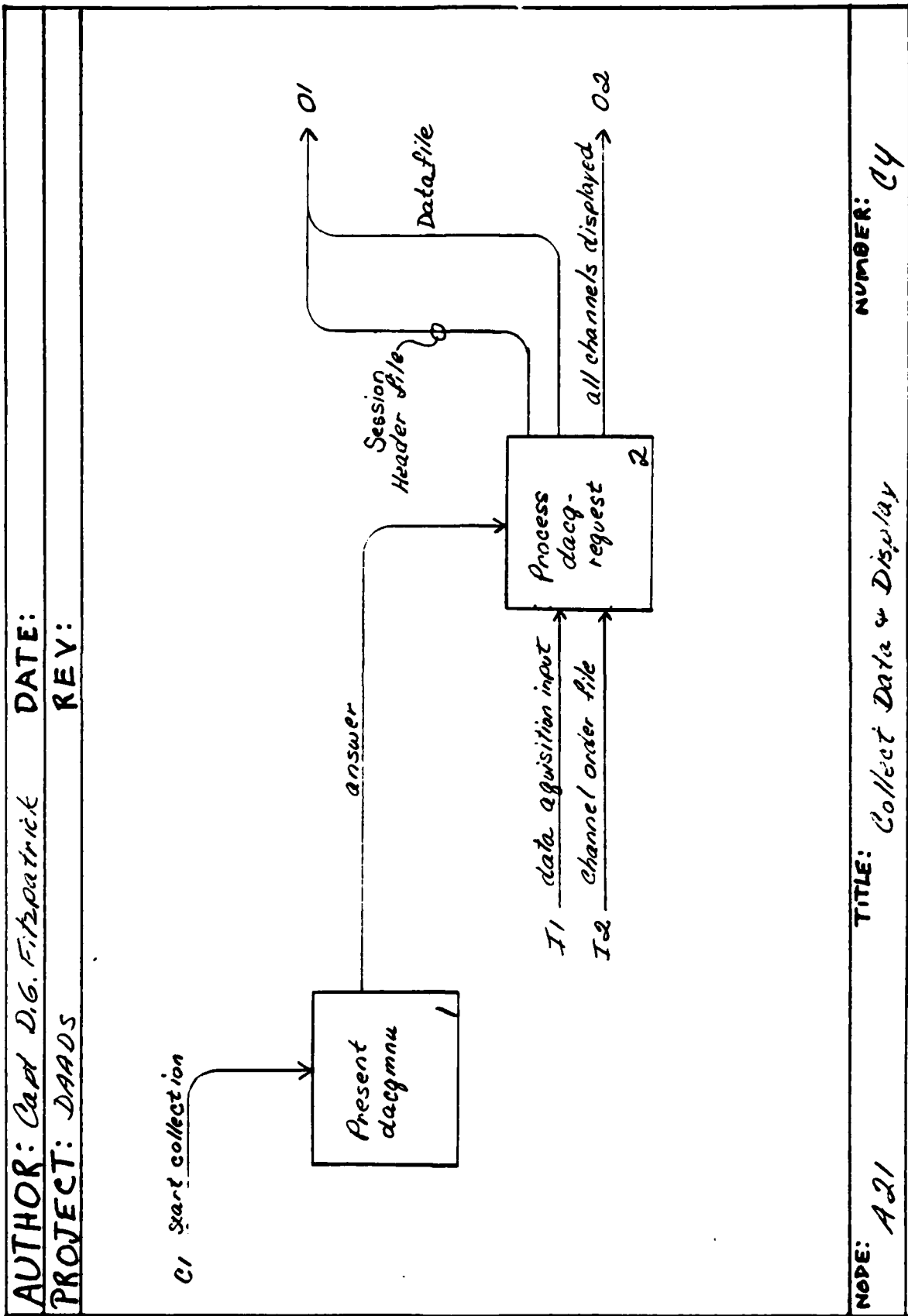
   A2122 Initialize Graphics - This routine extensively
uses MASSCOMP graphics routines to initialize the graphics
processor and graphics display.   Based on the number of
channels given by the user, graphics display segments are
created.   One segment for each channel up to a display
maximum of 12.   If more then 12 channels are collected in a
single session, the user is asked to state how many channels
to display. Channels are displayed in sequential order, top
to bottom, left to right.   This module also labels each
display based on an input file containing, in order, the
channel labels.

   A2123 Initialize data acquisition ports - This module
sets-up either the parallel or analog data acquisition port.
For parallel, simply open a path.   Additionally for analog
single channel, a clock is initialized and sampling fre-
quency information asked for.   Analog multiple channel col-
lection initializes two clocks for collection of frames of
channels.

   A2124 Collect analog data - The analog collection is
started and continues till user halts the process.   After
scaling for analog signals, writes the collected data to a
display buffer for access by the graphics processor.
Controls the display buffer to give graphics the appeerence
of motion across the display windo.Performs data reduction
by skipping frames of data. Based of number of channels per
frame, will skip the same number of frames.

   A2125 Collect Parallel - Parallel collection is started
and continues until user halts the process. After scaling
for parallel signals, writes the data to a display buffer

C1 start collection

Present dacgmnu 1

answer

I1 data acquisition input

I2 channel order file

Process dacg-request 2

Session Header file

O1

Data file

all channels displayed O2

A21 Collect Data & Display.

Abstract: The Collect Data & Display module presents a menu
asking the user for pertinent information for the data
collection. Information required includes how many channels
to collect, is collection analog or parallel, name of output
file, how many channels to display, the name of the session
and finally the name of the channel label file. After
initialization of the data acquistion and graphics proces-
sors, the data collection continues until user keyboard
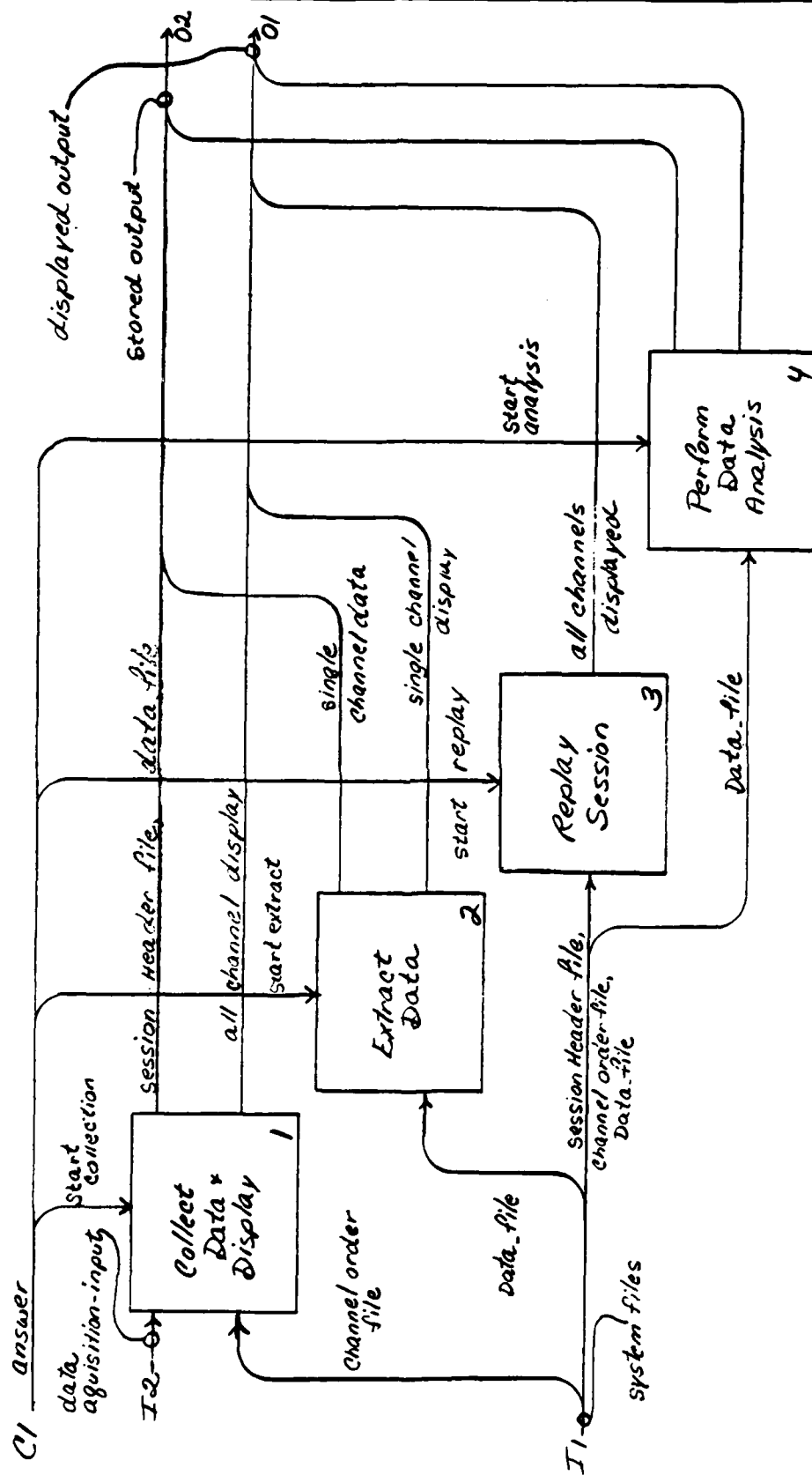input terminates the session.

    A211 Present dacqmnu - Presents the collection menu
asking the user to select how to identify the session. A
set-up file containing all necessary information   or
interactive input are the methods to chose from.   In either
case the user supplies the session name, the number of
channels and states if the collection is analog or parallel.
The number of channels ranges from 1 to 16.   Also, if it is
an analog collection, the user must supply the gain control
to increase low amplitude signals.   All of these questions
must be ansered before any other processing begins.   The
user is given the option to exit the menu to the next higher
menu, Present Menus, thus aborting any collection if this
menu was entered by mistake.

    A212 Process dacqrequest - This module determines the
function selected by the user and then branches to the
proper routine. If the selection is valid, a branch occurs,
if not, an error message is given and the Collect Data &
Display menu returns to the screen.   This happens until the
user gives a valid response.

AUTHOR: Capt D.G. Fitzpatrick   DATE:

PROJECT: DIAUS   REV:

C1   answer

Start collection

data aquisition-input

I2

Session Header file

all channel display

start extract

Collect Data + Display   1

Extract Data   2

Channel order file

Data_file

Replay Session   3

start replay

single channel data

single channel display

data file

displayed output   ∂2

stored output   O1

Perform Data Analysis   4

start analysis

all channels displayed

Data_file

Session Header file, channel order file, Data_file

system files

I1

NODE: A2   TITLE: Process main request   NUMBER: C3

A2 Process main request.

Abstract: The   Process main request module determines from
the data item answer the DAADS function selected by the
user.   If it is a valid answer, a simple transfer of control
occurs.   If not, a return to A1 happens.   This goes on until
the user gives a valid response.

A21   The Collect Data & Display module presents a menu
asking the user for pertinent information for the data
collection.   Information required includes how many channels
to collect, is collection analog or parallel, name of output
file, how many channels to display and the name of the
session.   After initialization of the data acquistion and
graphics processors, the data collection continues unti⌐¹
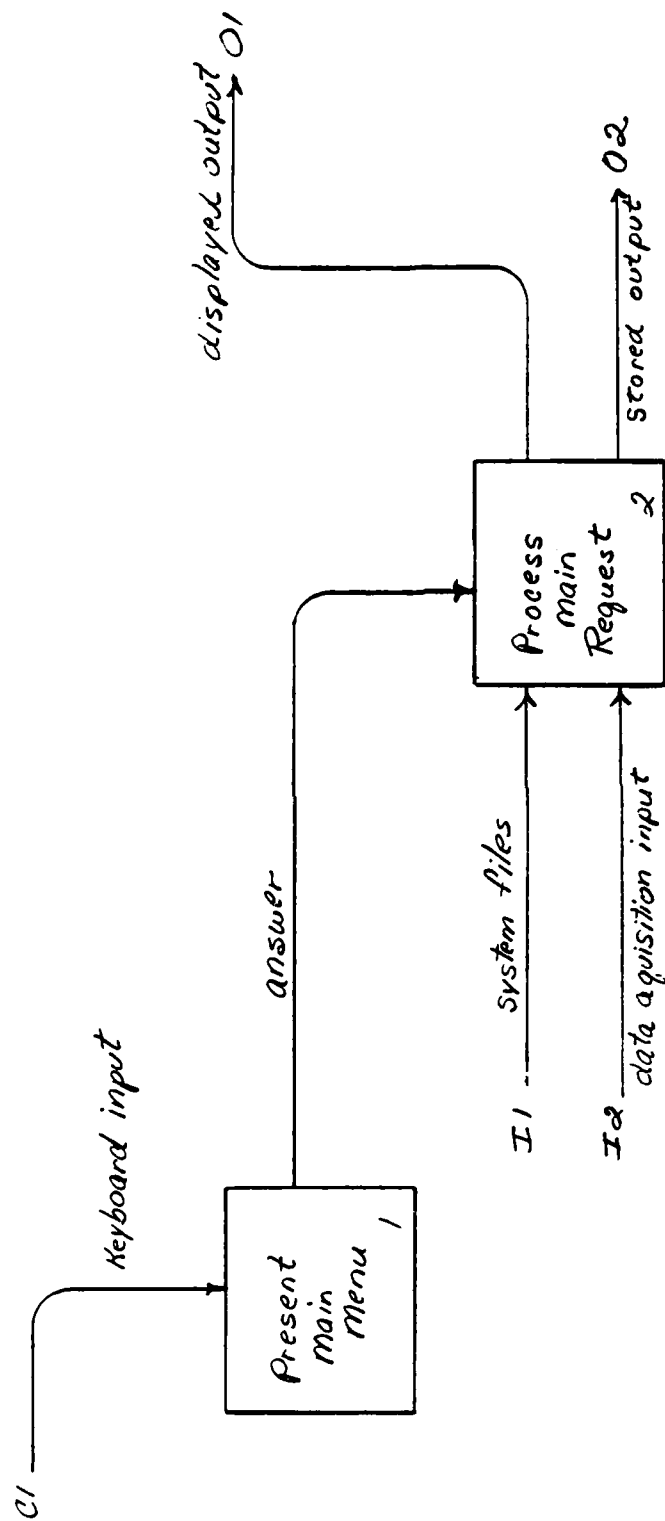user keyboard input terminates the session.

A22   The Extract Channel Data module is executed inde-
pendantly from the rest of DAADS.   This module separates
from an existing binary multi-channel file a single channel
of data.   During data collection, channels are stored with-
out separation to reduce the data processing load during
real-time operations.   Now, for later analysis, the channels
can be separated off-line and stored singlurally.   This
module will cycle so the user can extract several channels
without restarting the entire system.

A23   The Replay Session module allows the user to
replay off-line, biophysical data previously collected.
This provides an off-line review and analysis of data for
symptomatic and repetitive signals.

A24   The Perform Data Analysis module gives the user
access to signal anslysis routines.   These routines, to be
added in subsequent thesis work, are assumed to contain
whatever algorithms are deemed necessary for further bio-
physical data analysis in the study of motion sickness.

AUTHOR: Capt D.G. Fitzpatrick   DATE:
PROJECT: DAADS   REV:

C1

Keyboard input →

Present main Menu 1

answer →

Process main Request 2

displayed output → O1

stored output → O2

I1 ... System files →

I2 data aquisition input →

NODE: A0   TITLE: DAADS   NUMBER: C2

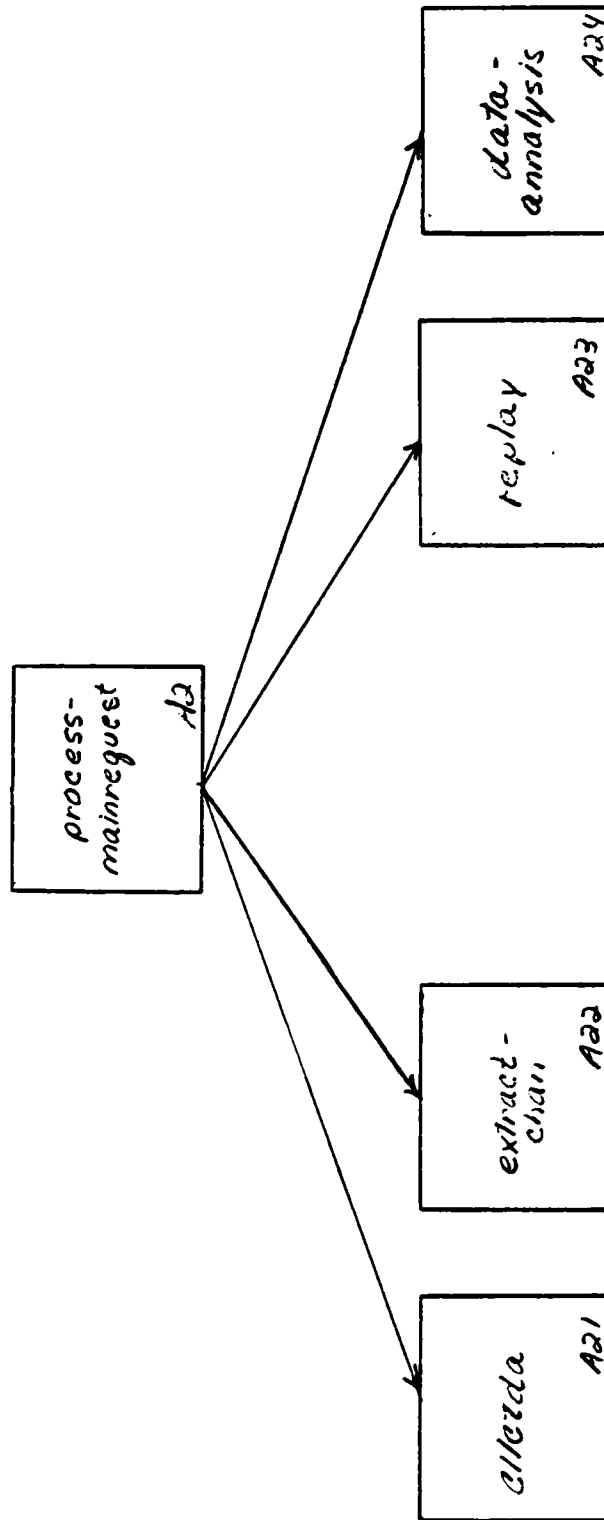D - 6

AO Data Acquisition and Display System (DAADS).

Abstract: This level presents the components of the DAADS.
These modules establish the control of the system over the
MASSCOMP computer.   From a presented menu the user can
select a function to collect, display and store data.   Or
the user can extract individual channel data from a multi-
channel existing file.   Also, the DAADS can replay or redis-
play a previous data collection session.

        A1   The Present main menu module displays on-screen the
first   menu.   This   menu asks the user to select the DAADS
function to exectue.   The user response determines the next
module of execution.   The menu will stay on the screen until
a valid response is received.

        A2   The Process main request module determines from the
data item answer the DAADS function selected by the user.
If it is a valid answer, a simple transfer of control
occurs.   If not, a return to A1 happens.   This goes on until
the user gives a valid response.

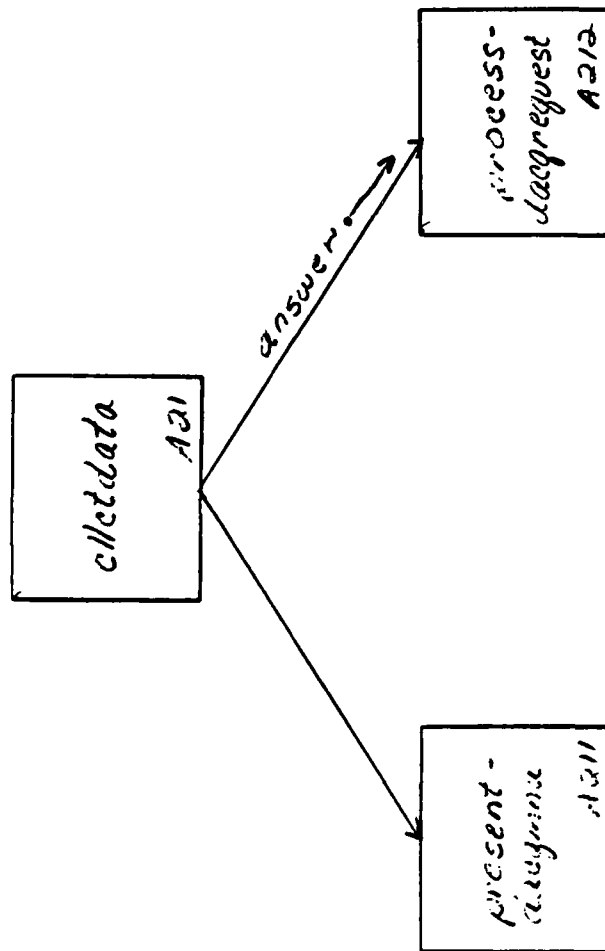AUTHOR: Capt D.G. Fitzpatrick   DATE:
PROJECT: DAADS   REV:

cllctdata
A21

answer

process-
dacqrequest
A212

present-
diagnosis
A211

NODE: A21   TITLE: cllctdata   NUMBER:

process-daegrequest   A212

collect-data   A2125

initda   A2124

data-flag

data flag

chanorder
nchans

initgraph-ics   A2123

chanorders

nchans
ndispchans
fnchanodr

inter-active-setup   A2122

data-flag, nchans, ndispchans

FILEIN, FILEOUT, dataflag, nchans, ndispchans

readsetup   A2121

data flag, nchans, ndispchans
INIT, nchanodr, FILEOUT
fnchanodr

collectdata
A2125

analogcollect
A21252

field collect
A21251

Extraction
A22

Present
Exton
A221

Coextraction
A222

replay
A23

initgraphics
A2/A3

Module Data Dictionary

NAME: daadsmnu

TYPE: Module

DATE:

NUMBER: AO

INPUTS: answer (user response to menu)

OUTPUTS: answer

GLOBAL VARIABLES READ: CR, NOTREADY, TRYANOTHER, TRYAGAIN, HITRETURN

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Presents the components of the DAADS. These modules extablish the control of the system over the system over the MASSCOMP computer. From a presented menu the user can select a function to collect, display and store data. Or the user can extract individual channel data from a multichannel existing file. Also, the DAADS can replay or redisplay a previous data collection session.

RELATED S.C. PROCESS: AO

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: A1 presentmenum, A2 processmainrequest

CALLING MODULES: None

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: presentmenum

TYPE: Module

DATE:

NUMBER: A1

INPUTS: None

OUTPUTS: Displayed DAADS Main menu

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Presents main menu on-screen. This menu asks the
user to select the DAADS function to execute.   The user
response determines the next module of execution.   The menu
will stay on the screen until a valid response is recieved.

RELATED S.C. PROCESS: A1

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: None

CALLING MODULES: daadsmnu

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: processmainrequest

TYPE: Module

DATE:

NUMBER: A2

INPUTS: Answer

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Determines fron the data item answer the DAADS
function selected by the user.   If it is a valid answer, a
simple transfer of control occurs.   If not, a return to Al
happens.   This goes on until the user gives a valid
response.

RELATED S.C. PROCESS: A2

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: A21 cllctdata, A22 extractchan, A23 replay,
A24 perform data analysis

CALLING MODULES: AO daadsmnu

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: cllctdata

TYPE: Module

DATE:

NUMBER: A21

INPUTS: None

OUTPUTS: answer

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Presents   a   menu asking the user for   pertinent
information for the data collection.   Information   required
includes how many channels to collect,   is collection analog
or   parallel,   name   of output file,   how many   channels   to
display   and the name of the session.   After initialization
of   the data aquisition and graphics processors,   the   data
collection   continues   until user keyboard input   terminates
the session.

RELATED S.C. PROCESS: A21

FILES READ: None

FILES WRITTEN: None

MODULES   CALLED: A211   presentdacqmnu,   A212
processdacqrequest

CALLING MODULES: A2 processmainrequest

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: presentdacqmnu

TYPE: Module

DATE:

NUMBER: A211

INPUTS: None

OUTPUTS: displayed dacqmnu

GLOBAL VARIABLES READ: None

GLOBAL VARIABLFS WRITTEN: None

FUNCTION: Presents the collection menu asking the user to select how to identify the session. A set-up file containing all necessary information or interactive input are the methods to chose from. In either case the user supplies the session name, the number of channels and states if the collection is analog or parallel. The number of channels ranges from 1 to 16. Also, if it is an analog collection, the user must supply the gain control to increase low amplitude signals. All of these questions must be answered before any other processing begins. The user is given the option to exit the menu to the next higher menu, Present Menus, thus aborting any collection if this menu was entered by mistake.

RELATED S.C. PROCESS: A211

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: None

CALLING MODULES: A21 cllctdata

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: processdacqrequest

TYPE: Module

DATE:

NUMBER: A212

INPUTS: answer

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Determines the function selected by the user and
then branches to the proper routine. If the selection is
valid, a branch occurs, if not, an error message is given
and the Collect Data & Display menu returns to the screen.
This happens until the user gives a valid response.

RELATED S.C. PROCESS: A212

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: A2121 read_setup, A2122 interactive_setup,
A2123 initgraphics, A2124 initda, A2125 collectdata

CALLING MODULES: A21 cllctdata

HARDWARE INPUT: None

HARDWARE OUTPUT: None

Appendix E

The following Structured Analysis and Design Technique (SADT) diagrams show the sturctural refinement of the PDCS requirements. The accompaning structure charts and data dictionay represent "as coded" PDCS composition.

Appendix contents

NAME: data_analysis

TYPE: Module

DATE:

NUMBER: A24

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: The Perform Data Analysis module gives the user access to signal analysis routines. These routines, to be added in subsequent thesis work, are assumed to contain whatever algorithms are deemed necessary for further biophysical data analysis in the study of motion sickness.

RELATED S.C. PROCESS: A24

FILES READ:

FILES WRITTEN:

MODULES CALLED:

CALLING MODULES: A2 processmainrequest

HARDWARE INPUT:

HARDWARE OUTPUT:

NAME: replay session

TYPE: Module

DATE:

NUMBER: A23

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: display_buff

GLOBAL VARIABLES WRITTEN: None

FUNCTION: The   Replay   Session module allows the   user   to
replay off-line, biophysical data previously collected.
This provides an off-line review and analysis of data for
symptomatic and repetitive signals.

RELATED S.C. PROCESS: A23

FILES READ: Session Header file

FILES WRITTEN: None

MODULES CALLED: A2123 initgraphics

CALLING MODULES: A2 processmainrequest

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: extractchan

TYPE: Module

DATE:

NUMBER: A22

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: The Extract Channel Data module is executed
independantly from the rest of DAADS. This module separates
from an existing binary multi-channel file a single channel
of data. During data collection, channels are stored
without separation to reduce the data processing load during
real-time operations. Now, for later analysis, the channels
can be separated off-line and stored singularly. This
module will cycle so the user can extract several channels
without restarting the entire system.

RELATED S.C. PROCESS: A22

FILES READ: Binary file containing channel data

FILES WRITTEN: Binary file containing single channel data

MODULES CALLED: None

CALLING MODULES: A2 processmainrequest

HARDWARE INPUT: None

HARDWARE OUTPUT: None

```
NAME:  analog_collect

TYPE:  Module

DATE:

NUMBER:  A21252

INPUTS:  None

OUTPUTS:  None

GLOBAL VARIABLES READ:   pathnum,  nframes,  NBUFFITEMS, bp,
offset,   fout,   DISPPOINTS,   FILEOUT,  nchans,  ndispchans,
write_flag, reduction_count

GLOBAL VARIABLES WRITTEN:  None

FUNCTION:    Processes  collected  analog  data.   Separates
channels  into individual display buffers.   Scales data for
display.   Performs data reduction by skipping over incoming
data  points.   Writes  all data points.

RELATED S.C. PROCESS:  A21252

FILES READ:  None

FILES WRITTEN:  FILEOUT

MODULES CALLED:  None

CALLING MODULES:  A2125 collectdata

HARDWARE  INPUT:   Analog input from MASSCOMP  AD12F  Analog
Converter

HARDWARE OUTPUT:  None
```

NAME: para_collect

TYPE: Module

DATE:

NUMBER: A2125

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: pathnum, nframes, NBUFFITEMS, bp, nchans, ndispchans, offset, fout, DISPPOINTS, FILEOUT, write_flag, reduction_count.

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Processes the collected parallel data. Separates channels into display buffers. Scales data appropriately for display. Performs data reduction by skipping over incomming data points. Writes all data points.

RELATED S.C. PROCESS: A21251

FILES READ: None

FILES WRITTEN: FILEOUT

MODULES CALLED: None

CALLING MODULES: A2125 collectdata

HARDWARE INPUT: parallel input form MASCOMP P16 parallel converter

HARDWARE OUTPUT: None

NAME: collectdata

TYPE: Module

DATE:

NUMBER: A2125

INPUTS: data_flag

OUTPUTS: None

GLOBAL VARIABLES READ: FILEOUT, pathnum, NBUFFITEMS

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Opens the output file FILEOUT. If can't, returns
error message then returns to cllctdata menu.   Starts the
data transfer based on data_flag.   1 = parallel transfer
mode, 2 = analog transfer mode.

RELATED S.C. PROCESS: A2125

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: A21251 para_collect, A21252 analog_collect

CALLING MODULES: A212 processdacqrequest

HARDWARE INPUT: None

HARDWARE OUTPUT: None

```
NAME:  initda

TYPE:  Module

DATE:

NUMBER:  A2124

INPUTS:  data_flag, nchans, chanorder

OUTPUTS:  None

GLOBAL  VARIABLES  READ:    NBUFFERS,  NBUFFITEMS,  nframes,
acqbuff, pinmask, pathnum, bp

GLOBAL VARIABLES WRITTEN:  NBUFFITEMS, nframes, pathnum, bp

FUNCTION:   Sets  up  either  the  parallel  or  analog  data
acquisition  port.    For  parallel,  simply  open  a  path.
Additionally   for   analog   single   channel,   a   clock   is
initialized  and  sampling frequency information asked  for.
Analog  multiple channel collection initializes  two  clocks
for collection of frames of channels.

RELATED S.C. PROCESS:  A2124

FILES READ:  None

FILES WRITTEN:  None

MODULES CALLED:  None

CALLING MODULES:  A212 processdacqrequest

HARDWARE INPUT:  None

HARDWARE OUTPUT:  None
```

NAME: create_segments

TYPE: Module

DATE:

NUMBER: A21233

INPUTS: dispbuff

OUTPUTS: None

GLOBAL VARIABLES READ: DISPPOINTS, display_buff

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Uses MASSCOMP unique graphics routine to create a graphics segment.   Segments are explained in the Graphics Manual (20).   Segments are created and used because of the MASSCOMP   feature   to   constantly   display   segments independent of the host or data aquisition process.

RELATED S.C. PROCESS: A21233

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: None

CALLING MODULES: A2123 initgraphics

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: place_windows

TYPE: Module

DATE:

NUMBER: A21232

INPUTS: Start, how many

OUTPUTS: None

GLOBAL VARIABLES READ: xl, yb, width, yt, realxl, realyb,
realxr, realyt

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Uses MASSCOMP unique graphics routines to define
graphics window. Each window wil display data from a single
channel.

RELATED S.C. PROCESS: A21232

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: None

CALLING MODULES: A2123 initgraphics

HARDWARE INPUT: None

HARDWARE OUTPUT: None

```
NAME:  initchanorder

TYPE:  Module

DATE:

NUMBER:  A21231

INPUTS:  nchans, chanfile

OUTPUTS:  chanlabel, chanorder

GLOBAL VARIABLES READ:

GLOBAL VARIABLES WRITTEN:  reduction_count

FUNCTION:   Reads  the channel order file to obtain the user
desired  order of input channels,  secondary reduction  rate
and  also,  for  each channel,  reads  the  supplied  label.
Channel numbers are two digits long (00,01...15),  secondary
reduction  rates are four digits long and channel labels are
a maximum of 20 characters.   A single blank separates these
three fields of information.

RELATED S.C. PROCESS:  A21231

-FILES READ:  chanfile

 FILES WRITTEN:  None

 MODULES CALLED:  None

 CALLING MODULES:  A2123 initgraphics

 HARDWARE INPUT:  None

 HARDWARE OUTPUT:  None
```

NAME: initgraphics

TYPE: Module

DATE:

NUMBER: A2123

INPUTS: data_flag, nchans, ndispchans, fnchanodr, chanorder

OUTPUTS: chanorder

GLOBAL VARIABLES READ: chanlabel, DISPPOINTS, MAXWINDOWS

GLOBAL VARIABLES WRITTEN: offset, realxl, realyb, realxr, realyt

FUNCTION: Extensively uses MASSCOMP graphics routines to initialize the graphics processor and graphics display. Based on the number of channels given by the user, graphics display segments are created. One segment for each channel up to a display maximum of 12. If more than 12 channels are collected in a single session, the user is asked to state how many channels to display. Channels are displayed in sequential orde, top to bottom, left to right. This module also labels each display based on an input file containing, in order, the channel labels.

RELATED S.C. PROCESS: A2123

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: A21231 initchanorder, A21232 placewindows, A21233 create_segments

CALLING MODULES: A212 processdacqrequest

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: interactive_setup

TYPE: Module

DATE:

NUMBER: A2122

INPUTS: None

OUTPUTS: data_flag, nchans, ndispchans, fnchanodr, FILEOUT

GLOBAL VARIABLES READ: MAXWINDOWS

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Asks user specific question to obtain set-up
information. Information includes collection mode; parallel
or analog (data_flag), number of channels to collect
(nchans), number of channels to display (ndispchans), name
of channel order file (fnchanodr), the name of the output
file (FILEOUT), and finally the name to identify the session
by (for Session Header file name).

RELATED S.C. PROCESS: A2122

FILES READ: None

FILES WRITTEN: Session Header file

MODULES CALLED: None

CALLING MODULES: A212 processdacqrequest

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: read_setup

TYPE: Module

DATE:

NUMBER: A2121

INPUTS: filename

OUTPUTS: data_flag, nchans, ndispchans, fnchanodr,FILEOUT

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Reads from the file 'filename' the set-up
parameters, data_flag, nchans, ndispchans, fnchanodr and
FILEOUT and Session name.

RELATED S.C. PROCESS: A2121

FILES READ: filename

FILES WRITTEN: Session Header file

MODULES CALLED: None

CALLING MODULES: A212 process

HARDWARE INPUT: None

HARDWARE OUTPUT: None

PDCS SADT

NODE INDEX

A-0   Progamable Digital Collection Software

Abstract: At this level the entire PDCS is shown. The PDCS
for the PDCE is designed to input analog biophysical sig-
nals, control the channel digitization and send the digital
signal to the MAC through the SICM.   Inputs include the
analog signals from the transducers on the patient.   Key-
board inputs receive user directions indicating the PDCS
function to perform.   Outputs are the digital signal to the
SICM and a signal to the remote terminal controling the CIM
on-board computer.
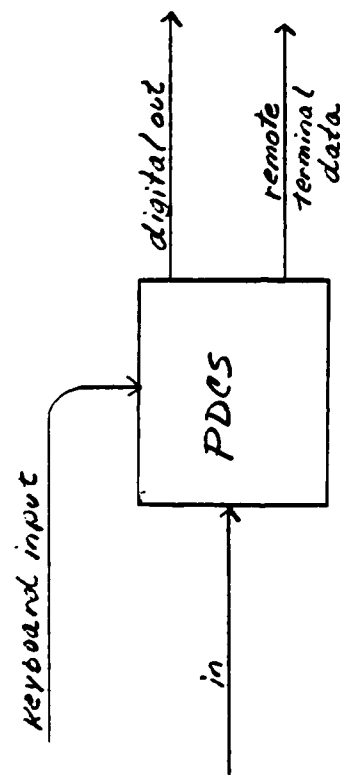
NODE: A-0   TITLE: PDCS   NUMBER:

AO Programable Digital Collection Software (PDCS).

Abstract: This   level shows the components of PDCS.   Five
functions allow the user to collect data, test the chair-MAC
interface, display channel outputs, and display help text.

     A1   The Present PDCS module generates the five function
menu and gets the user's selection.   If the   selection   is
valid   the   function is executed,   otherwise,   the   user   is
prompted for another try.

     A2   The Collect data module collects subject data from
user   selected   channels at user selected sample   rates   and
transmits the data to the MAC as a 16 bit word consisting of
a 12 bit data field with a channel ID appended to the upper
4-bit field.

     A3   The Test MAC-Chair interface module generates a 16
bit pattern at a fixed rate to test the MAC-Chair interface.
The   rate is a function of what the software execution   rate
happens to be.   The test pattern consist of an incremented
8-bit   counter   sent   to the PDCS's lower and   upper 8-bit
output ports.

     A4   The Display channels module allows the user to List
or Plot channel outputs at the remote display terminal at a
rate fixed to the software execution speed.   By viewing the
display,   the user can determine the proper setup and   oper-
ation of the subject tranducers and digitizer circuits.

     A5   The Display help text module displays a single
screen help text explaining the function of each menu selec-
tion.   This text is not meant to be sufficiently detailed to
guide an unfamiliar user through all phases of the   PDCS
capabilities but only as an occasional prompter until the
user becomes totally familiar with the PDCS operation.

AUTHOR: Capt D.G. Fitzpatrick   DATE:
PROJECT: PDCS   REV:

TITLE: PDCS
NODE: A0   NUMBER:

E - 6
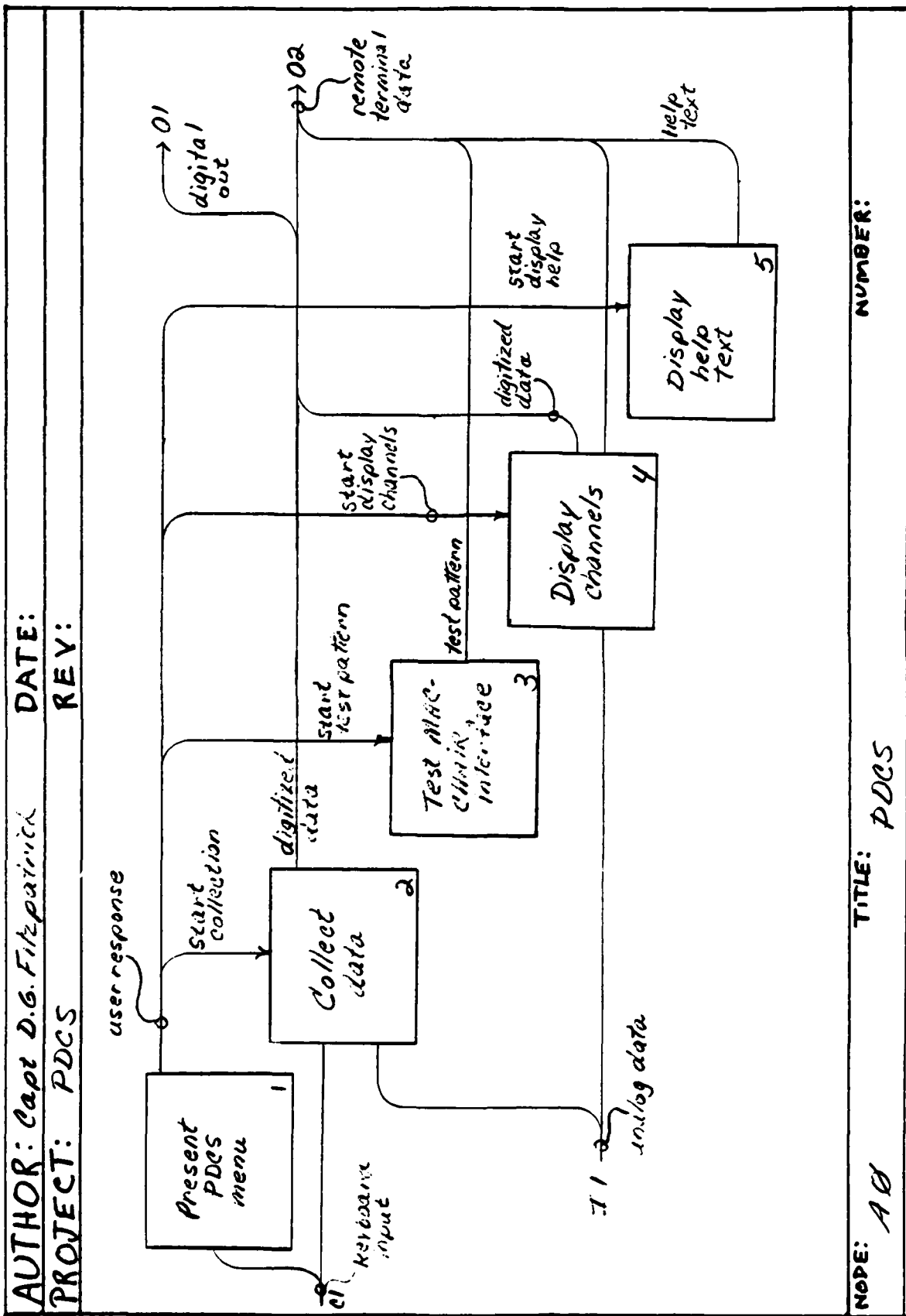
A2 Collect data

Abstract: The Collect data module collects subject data from user selected channels at user selected sample rates and transmits the data to the MAC as a 16 bit word consisting of a 12 bit data field with a channel ID appended to the upper 4-bit field.

A21 Get number of channels – This module allows the user to decide the last channel (0-15) sampled in the samp- ling sequence which always begins with channel 0.   The user will not be able to skip channels in the sequence.   For example, if the user decides to collect only four channels, an entry of '3' tells the program to collect channels 0,1,2,3.

A22 Calculate sample rate – This module allows the user to select 1 of 8 sample rates.   The maximum rate is a function of the software execution rate and can be adjusted by inserting additional software delay. The current maximum sample rate is 370 Hz. Selectable rates are modulo 2 of the maximum rate, e.g. the second highest rate is half the maxi- mum, the third highest rate is a fourth of the maximum, etc.

A23 Digitize channels – This module samples the selec- ted channels at the selected sample rate.   The sampling always begins with channel 0 and ends with the channel selected in A21. If the last channel is not channel 15 then A23 internally dummy digitizes the remaining channels to maintain the proper sampling interval. Dummy digitization prodeuces no data.   Only valid channel data are sent to the MAC.

C1 start collection

I1 keyboard input

Get number of channel 1

nchan

Calculate sample rate 2

sample rate

Digitize channels 3

digitized data O1

I2 analog data
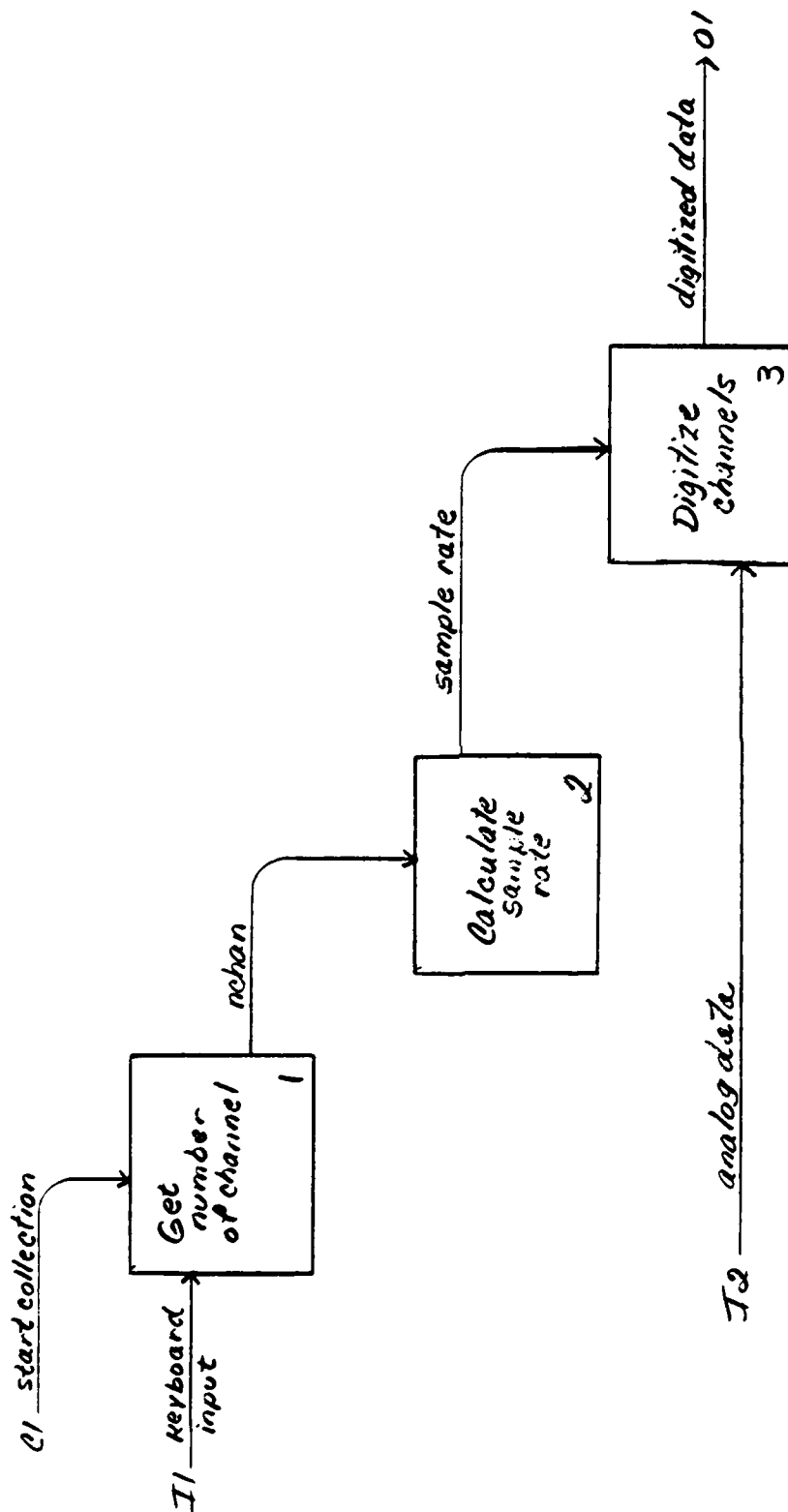
TITLE: Collect data

NODE: 1/2 NUMBER:
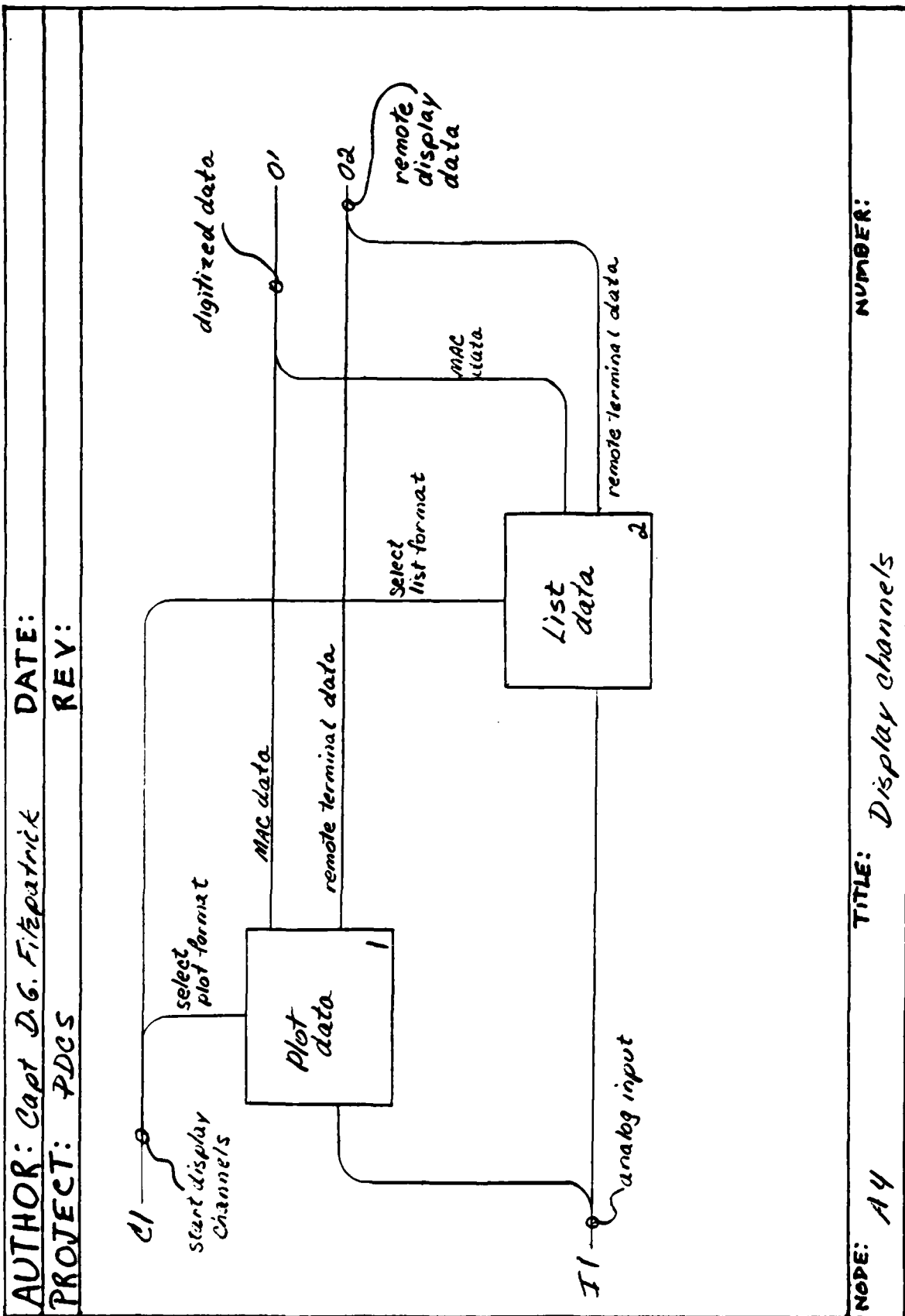
E - 8

A4 Display channels

Abstract: The Display channels module allows the user to List or Plot channel outputs at the remote display terminal at a rate fixed to the software execution speed. By viewing the display, the user can determine the proper setup and operation of the subject tranducers and digitizer circuits. All 16 channels are sampled at a rate fixed by the execution rate of the PDCS software. The channel outputs are also available to the MAC.

A41 Plot data - By selecting this module, the sampled channel are displayed a psuedo bar graph format. The 16 bit data are displayed on the remote terminal relative to the 4 bit channel ID value and the 12 bit subject data value. The channel ID determines the row position on the display, and the 12 bit subject data value determines the column position. The display can be frozen to better view the outputs.

A42 List data - By selecting this module, the sampled data are displayed in tabular form. All 16 channels are displayed on the same row. The channel ID field determines the column position. The display can be frozen to better view the outputs.

AUTHOR: Capt D.G. Fitzpatrick   DATE:
PROJECT: PDCS   REV:

C1 — start display channels

select plot format

MAC data

remote terminal data

plot data 1

analog input

T1

select list format

list data 2

remote terminal data

MAC data

digitized data — O1

O2 — remote display data

mac data

TITLE: Display channels

NODE: A4   NUMBER:

E - 10
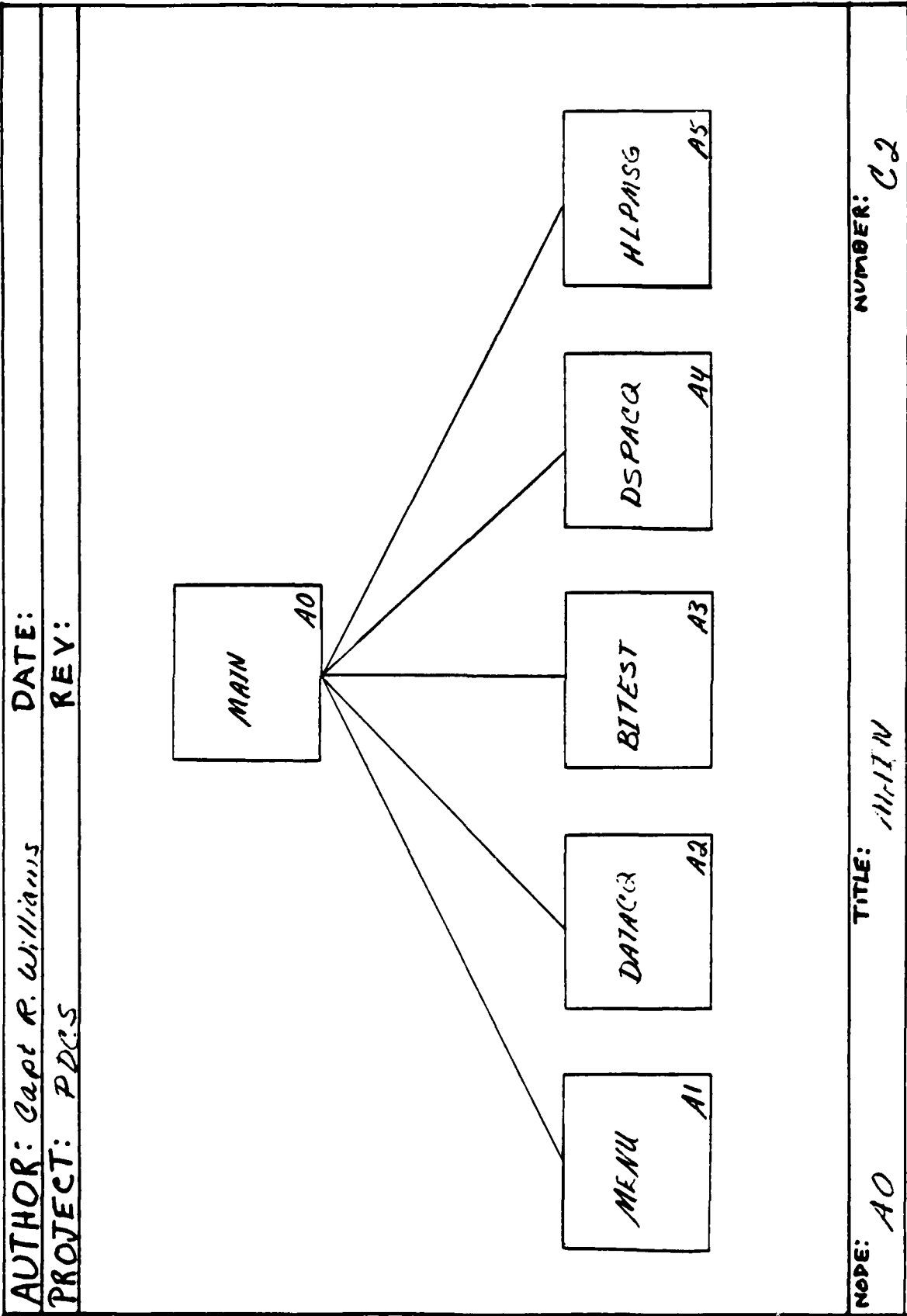
AUTHOR: Capt R. Williams   DATE:

PROJECT: PDCS   REV:

NODE: AO   TITLE: MAIN   NUMBER: C2

MAIN   AO

MENU   A1

DATACQ   A2

BITEST   A3

DSPACQ   A4

HLPMSG   A5

Module Data Dictionary

NAME: MAIN

TYPE: Module

DATE:

NUMBER: AO

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Main driver for PDCS

RELATED S.C. PROCESS: AO

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: A1 MENU, A2 DATACQ, A3 BITEST, A4 DSPACQ, A5 HLPMSG

CALLING MODULES: None

HARDWARE INPUT: None

HARDWARE OUTPUT: None

Appendix G

DAADS operating procedures, while kept basically simple, assume the operator has reached an understanding of the Unix operating system in general and of the file system in particular. Also, knowing how to use at least one system text editor is neccessary to create the required channel order and standard set-up files.

A basic understanding of DAADS operating procedures means knowing what the menu options are asking for, how to make external analog clock connections, what error messages could occur, and finally, how to start up the DAADS program. To further ilustrate using DAADS, an example session including a step by step procedure, summarizes the DAADS operating procedures.

To the Unix operating system, DAADS is just another program waiting in some file for a chance to perform. The performance starts by the user telling Unix the file name where DAADS is waiting. Once activited, DAADS presents a series of menu options. A response from the operator will tell DAADS what to do next.

Menu Response Actions

Each menu module presents a heading stating the module funciton. The options displayed further refine actions within this function. At the lowest level, specific questions ask for information needed to complete the chosen

```
Contents of                     Contents of
Channel order file              Set-up file

00 0001 Ecg                     06
01 0002 Egg                     04
02 0001 Eng                     02
03 0003 Face PP                 Jones, Tom
04 0001 Finger PP               Jones.datafile
05 0001 Eig                     chanordfile.dat
```

Example F.1   Channel order file and
                system set-up file.

Both of these files are created by using a system text editor, inputing the information in the correct format and then saving the file to the desired name. It is left to the user to keep track of file content.

system initialization information normally interactively supplied from the keyboard. This file, when used by DAADS module read_setup, relieves the user from having to input standard information everytime a data collection is started.

Each item of information is on a separate line and all the information listed must be supplied in the order shown. Item format is very similiar to the channel number and channel label explained above. The explanations shown in Table F - 2 do not appear in the acutal file but are presented to better clarify the file content.

Content   Explanation

Content		Explanation
16	* *	Number of channels to collect. Two digits. Maximum of 16 channels.
09	* *	Number of channels to display. Max. is 12.
01	* *	collection mode. 01 = parallel, 02 = analog
Session Name	*	Session identifier, 20 char maximum.
Output file	* *	Output file name. 20 char maximum. If already exists, current content erased.
Channel order file name	* * *	File name of channel order file. Maximum of 20 characters.

Table F - 2. System set-up file content.

To illustrate how to use these files, consider a data collection where six channels will be collected for Tom Jones. Only four channels are wanted for display but all six will be stored for later replay and analysis. Thus, use the following files:

characters with imbedded blanks permitted. Any printable
keyboard character is permited.

The channel label, secondary reduction rate and channel
number must be separated by one blank.

More than one channel order file is permitted in the
DAADS system. Each channel order file resides in its own
disk area under a unique file name. Then, at system set-up,
the desired channel order file is identified through the
file name given by the user.

Channel order file content has each channel number,
secondary reduction rate and label on a single line and must
match the following example in Table F - 1.

Content			Explanation
00 0001 label one	*	The explanations do not appear in
01 0001 label two	*	the file.
02 0001 label three	*	The first two digits represent
03 0001 label four	*	the channel number. Two digits must
04 0001 label five	*	be used.
05 0001 label six	*	Leave a blank separating the channel
06 0001 label seven	*	number and the secondary reduction
07 0001 label eight	*	rate and the channel label.
08 0001 label nine	*	Labels can be up to 20 characters
$\frac{1}{2}$	*	long or may be left blank. Internal
	*	blanks are permitted in the labels.
$\frac{1}{2}$		
	*	At this point the maximum number
$\frac{1}{2}$	*	of channels the user can collect
	*	with this channel order file is 9.
$\frac{1}{2}$		
	*	Sixteen channels may be listed
15 label sixteen	*	numbering from 00 to 15.

Table F - 1. Channel order file content.

The system set-up file, Table F - 2, contains the

Appendix F

Two user controled files for the MASSCOMP DAADS software are the channel order file and the system set-up file.

The channel order file contains channel numbers listed with the correct secondary reduction rate and label for each particular channel. The listed order of the channels tells DAADS the input order to expect at the data acquisition device. Also, the number of channels on the list must be equal to or greater than the number of channels selected for input. DAADS module Initchanorder uses the number of channels input from the set_up routines to determine how many times to read the list in the channel order file. An attempt to read more channels than listed produces an error message "Not enough channels in channel order file". The user is returned to the Cllctdata menu.

Within the channel order file, Table F - 1, channel numbers are two digits long. For listing channel number one use a 01 and for channel fifteen use 15. The channel numbers range from 0 to 15 for a maximum of 16 channels.

The secondary reduction rate is four digits long. The smallest value is 0001; representing no secondary reduction. A value of 0002 means one-half reduction, 0003 equates to one-third, 0010 gives one-tenth reduction and so on.

Finally the label for each channel is a maximum of 20

NAME: LIST 16

TYPE: Module

DATE:

NUMBER: A42

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Displays sampled data in tabular form.   All   16
channels   are   displayed on the same row.   The   channel   ID
field   determines the column position.   The display can   be
frozen to better view the outputs.

RELATED S.C. PROCESS:

FILES READ: None

FILES WRITTEN: None

MODULES CALLED:

CALLING MODULES:

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: PLOT16

TYPE: Module

DATE:

NUMBER: A41

INPUTS: None

OUTPUTS: None

GLOB.. VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: The sampled channels are displayed a psuedo bar
graph format.   The 16 bit data are displayed on the remote
terminal relative to the 4 bit channel ID value and the 12
bit subject data value.   The channel ID determines the row
position on the display, and the 12 bit subject data value
detrermines the column position.   The display can be frozen
to better view the outputs.

RELATED S.C. PROCESS: A41

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: None

CALLING MODULES: A4 DSPACQ

HARDWARE INPUT: Digitized channel data

HARDWARE OUTPUT: H19 CRT display

NAME: DSPACQ

TYPE: Module

DATE:

NUMBER: A4

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Allows the user to List of Plot channel outputs
at the remote display terminal at a rate fixed to the
software execution speed.   By viewing the display, the user
can determine the proper setup and operation of the subject
tranducers and digitizer circuits.   All 16 channels are
sampled at a rate fixed by the execution rate of the PDCS
software.   The channel outputs are also available to the
MAC.

RELATED S.C. PROCESS: A4

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: A41 PLOT16, A42 LIST16

CALLING MODULES: AO MAIN

HARDWARE INPUT: None

HARDWARE OUTPUT: None

NAME: BITEST

TYPE: Module

DATE:

NUMBER: A3

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Generates a 16 bit pattern at a fixed rate to test the MAC-Chair interface. The rate is a function of what the software execution rate happens to be. The test pattern consist of an incrememted 8-bit counter sent to the PDCS's lower and upper 8-bit output ports.

RELATED S.C. PROCESS: A3

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: None

CALLING MODULES: MAIN

HARDWARE INPUT: None

HARDWARE OUTPUT: The bit test pattern sent to the MAC-Chair interface.

NAME: DIGCHN

TYPE: Module

DATE:

NUMBER: A23

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Samples the selected channels at the selected
sample rate. The sampling always begins with channel 0 and
ends with the channel selected in A21. If the last channel
is not channel 15 then A23 internally dummy digitizes the
remaining channels to maintain the proper sampling interval.
Dummy digitization produces no data. Only valid channel
data are sent to the MAC.

RELATED S.C. PROCESS: A23

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: NONE

CALLING MODULES: A2 DATACQ

HARDWARE INPUT: Analog inputs from BDAS on-chair
Biophysical monotoring transducers

HARDWARE OUTPUT: Digitized parallel output to MAC
(MASSCOMP)

NAME: INITSR

TYPE: Module

DATE:

NUMBER: A22

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Allows the user to select 1 of 8 sample rates.
The maximum rate is a function of the software execution
rate and can be adjusted by inserting additional software
delay.   The current maximum sample rate is 370 Hz.
Selectable rates are modulo 2 of the maximum rate, e.g. the
second highest rate is half the maximum, the third highest
rate is a fourth of the maximum, etc.

RELATED S.C. PROCESS: A22

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: None

CALLING MODULES: A2 DATACQ

HARDWARE INPUT: Keyboard responses

HARDWARE OUTPUT: None

NAME: GETCHN

TYPE: Module

DATE:

NUMBER: A21

INPUTS: None

OUTPUTS: Number of channels

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Allows the user to decide the last channel (0-15) sampled in the sampling sequence wich always begins with channel 0. The user will not be able to skip channels in the sequence. For example, if the user decides to collect only four channels, an entry of '3' tells the program to collect channels 0,1,2,3.

RELATED S.C. PROCESS: A21

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: None

CALLING MODULES: A2 DATACQ

HARDWARE INPUT: Keyboard responses

HARDWARE OUTPUT: None

NAME: DATACQ

TYPE: Module

DATE:

NUMBER: A2

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Collects subject data from user selected channels at user selected sample rates and transmits the data to the MAC as a 16 bit word consisting of a 12 bit data field with a channel ID appended to the upper 4-bit field.

RELATED S.C. PROCESS: A2

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: A21 GETCHN, A22 INITSR, A23 DIGCHN

CALLING MODULES: AO Main

HARDWARE INPUT: Keyboard responses

HARDWARE OUTPUT: None

NAME: MENU

TYPE: Module

DATE:

NUMBER: A1

INPUTS: None

OUTPUTS: None

GLOBAL VARIABLES READ: None

GLOBAL VARIABLES WRITTEN: None

FUNCTION: Generates the five function menu and gets the
user's selection. If the selection is valid the function is
executed, otherwise, the user is prompted for another try.

RELATED S.C. PROCESS: A2

FILES READ: None

FILES WRITTEN: None

MODULES CALLED: None

CALLING MODULES: AO MAIN

HARDWARE INPUT: Keyboard input

HARDWARE OUTPUT: CRI displayed menu

function. The menu modules include the Main Menu, Data Acquisition and Display, Extract Single Channel, Replay, and Perform Data Analysis.

Main Menu Module. Presents four options, each representing the four main DAADS functions. The options:

1. Data Collection and Display. Provides the path to the MASSCOMP data acquistion and graphics display. Used for collecting and displaying real-time data. The primary function of DAADS, this option selection causes a transfer to the Data Acquisition and Display Menu Module.

2. Extract a channel from a file. Selected when the operator wants to separate single channel data from a file containing multiple channel data information. Selection transfers control to the Extract Single Channel Menu Module.

3. Replay a previous collection. Used to review a previous collection session. The display is identical to original collection but data comes from the original stored data file. Transfers control to Replay Menu Module.

4. Perform data analysis. Provides the path to future data analysis routines. Currently nothing exists below this menu option.

Data Acquisition and Display Menu Module. The primary function of DAADS. From here real-time data collection and display begins, but first three more options.

1. Use standard set-up file. If collection session parameters come from a standard file, use this selection. Now at lowest level, DAADS asks for the standard set-up file name. This file is the same system set-up file created in appendix F.

    DAADS then verifies file existence, reads and displays parameters and, if the given output or Session Header file exists, ask permission to over write their contents. Denied permission forces return to previous menu level.

2. Interactive set-up options. Basically does same as first option, but operator supplies information in response to specific questions. A '0' response to any question returns control to previous menu level. All parameters are displayed giviing operator option to accept or reject. At this point, if any parameter was input incorrectly the set-up process can be restarted by rejecting.

3. Collect data and display. This option is accepted by DAADS only after completing option 1 or 2. If set-up is completed, this option starts the MASSCOMP data acquisition and graphics processors. At this point data collection and display physically begins. DAADS now gives to operator two more options. "W - Begins/end data storage" and "Q - quits data collection".

Typing a W starts or stops the physical data storage to the output file. Initially data is only displayed not stored. Entering a Q quits the data collection session, closes all files and forces an exit from DAADS back to Unix. The exit from DAADS is neccessary to completely halt the data acquisition and graphics processors.

<u>Extract Single Channel Menu Module</u>. Displays two new options; Start extraction and Exit menu.

1. Start extraction. Starts the extraction process by asking specific low level questions. The operator supplies information needed to separate a single channel from a multiple channel data file. The questions and expected responses:

a. "The number of channels per frame" - When originally collected, MASSCOMP groups channel samples together in frames of information (21:1-11). The number of channels collected is the number of channels in each frame. For example, if 12 channels were originally collected, answer this question with 12.

<u>CAUTION</u> The program beleives what the operator tells it. Should the data file really contain other than 12 channels per frame, unexpected results will occur.

G - 3

b.   "The channel number to extract" –
     Appropriate channel numbers range from 1
     to 16.

c.   "Is the input file the same?" – Allows
     operator to extract, one at a time,
     several channels from the same data file
     without re-entering file name. Question
     asked only on second or subsequent ex-
     tractions.

d.   "The EXISTING Binary input file name" –
     operator enters the name of the data
     file containing previously collected
     data. If on second or subsequent ex-
     traction and question 'c' answered yes,
     this question is skipped.

e.   "Output file name" – Give file name
     where extracted channel data will be
     placed.

f.   "Is input collected as parallel (1) or
     analog (2)" – DAADS want to know if
     the original collection mode was par-
     allel or analog.

     CAUTION.   Again, DAADS takes the
     operator at his word. Be correct to
     avoid unpredictable results.

g.   "Display during extraction" – Yes and
     the channel data is displayed as
     extracted. No, and the extraction
     progresses without the display. The
     extraction time is much faster when not
     displaying data.

h.   "Would you like to do another extrac-
     tion?" – Give opportunity to extract
     another channel without having to
     traverse through higher level menu op-
     tions.

2.   Exit menu. If Extract module entered by mistake,
     this option lets operator exit without having to
     start an extraction.

Replay Module.   Presents two options, Start Replay and

Exit menu.

1. Start Replay. Selecting this option prompts DAADS to ask for the Session Header file name. This file contains the original session parameters stored when session first run. These same parameters are necessary to recreate the data display.

   DAADS ensures existence of the Session Header file name and any files read as parameters. If all is correct, DAADS displays the content for operator acceptance or rejection. Accpetence starts the replay, rejection returns to Replay menu.

2. Exit menu. Allows operator to return to Main Menu.

Perform Data Analysis Menu Module. All options except Exit will ask the operator to make another selection. The Data Analysis routines exists in future developments. This menu merely provides a place to attach whatever routines are deemed necessary for futrue research.

Analog Clock Connection

MASSCOMP analog data acquisition requires clock pulses to sample incomming signals. In addition to normal data acquisition processor set-up, DAADS also initializes the programmable CK10 clock module (21:1-10,A-11). The CK10 module produces the clock pulses to drive the data collection.

To collect analog data, the operator must connect the clocking signal to the AD12f A/D converter. MASSCOMP Data Acquisition Programming Manual explains how to make these connections (21:1-10,A-12)

DAADS initializes CLK0 and CLK1 on the CK10 clock

module for multiple channel collections. Only CLK0 is used for single channel collecting. The sampling rate, CLK0, is preset to 160 Hz and the converter clock, CLK1, at 1000 Hz.

The output from CLK0, the slower sampling rate clock, is attached to the gate input 'C' of CLK1. Output from CLK1 goes to the 'CLK' input on the AD12F converter. For single channel collection, the output of CLK0 goes directly to the AD12f CLK input.

With the output of CLK0 attached to the 'C' gate input of CLK1, the CLK1 output becomes a 160 Hz burst of clock pulses (21:1-11). The number of pulses within a burst equals the number of channels collected. This is how a 'frame' of data is collected

Error Messages

Error messages can come from four sources; DAADS, data acquisistion processor, graphics processor and the Unix operating system. Except for the DAADS messages all others are fatal to DAADS program execution. Some are even fatal to system execution and force the operator to perform system reboot.

The following error messages include only those generated by DAADS and the system errors likely to occur during DAADS execution. Interactive messages requesting corrected user input were not considered errors.

DAADS Generated Errors.

.

1. "Can't open chanorder file" - The channel order file name doesn't exist within the directory given by the operator. Check spelling of directory and file names. If spelling correct, file simply does not exist in the given directory. Make sure directory used is the correct one.

2. "Channel number in channel order out of range" - Within the channel order file a given channel exceeds channel numbering range (0 to 15). Check the channel order file content.

3. "Not enough channel numbers in chanorder file" - The channel order file must contain information for at least the number of channels collected. If not, this error results.

4. "Number of cha.¬els input is out of range" - Within the system standard set-up file the number of channels to collect exceeds the boundries 1 to 16.

5. "Set-up file does not have all required parameters" The system standard set-up file explained in appendix F, must contain; number of channels to collect, number of channels to display, collection mode, Session name, output file name and the channel order file name. One or more of these was not in the given set-up file.

6. "Incorrect collection mode detected" - The set-up file collection mode is not a 01 or 02.

7. "Channel order file does not exist" - The channel order file name given does not exist within the file directory given. Check spelling of directory and file names. If spelling correct, file simply does not exist in directory given. Ensure directory given is the directory wanted.

8. "Error in opening (filename)" - The (filename) could not be opened. Usual reason, Unix can not locate the file matching (filename). Check the file directory given, check spelling.

Data Acquisition Processor Generated Errors. A few errors generated occur because of input buffers filling up or a data acquisition path is busy.

1. "Incomplete transfer on path 1" - The data ac-

quisition routine has filled all input buffers and has no room left to continue transfering. Exit DAADS before restarting a data collection function. Leaving DAADS automatically discards the buffers so on reentry all buffers start empty.

2.   "Path is in use" - A data acquisition path is still seen as busy. Occurs because DAADS was unable to completely stop data transfering. Exit DAADS before restarting a data collection function.

Graphics Processor Errors. These errors are fatal to DAADS execution. The operator must restart DAADS.

1.   "Fatal(mgrscaley) - Viewport <n> is undefined" - The graphics processor tried to create a display on a non-existent display window. Error is fatal to DAADS execution. Occurs because the graphics processor is still executing while DAADS changes execution parameters. Restart DAADS.

2.   "Fatal(mgiasngp) - Unable to assign graphics processor" - Occurs because DAADS attempted to assign the graphics processor before that processor was deassigned. Reset the graphics processor and restart DAADS.

Operating System Errors. The most cryptic error messages. Unix can and does send out many different error messages. Those comming from DAADS execution could originate for any number of reasons.

"Segmentation error(core dumped)" - Usually happens because the running program tried to access a memory address beyond its boundries. What causes this attempted access is hard to determine. Computational errors, run-a-way loops, incorrect input values are some common reasons.

Most causes for this error are beyond many user's programming abilities. If all inputs are correct, the fix requires detailed code understanding. Should this problem

G - 8

persist, seek help from a person knowledgeable in Unix and 'C' programming.

Steps for Using DAADS

The following steps show by example how to use DAADS.

The situation: Collect 5 analog channels, display 4, use the standard set-up file called Session_setup, put output to file 'BIO', and use a channel order file named 'chanorder'. Store the session set-up parameters in file 'Session_header'.

The Steps:

1. Using a Unix text editor, create the system standard set-up file, Session_setup. From the description in appendix F, file content becomes

    ```
    05
    04
    02
    Session_header
    BIO
    chanorder
    ```

2. Again using a Unix text editor, create the channel order file 'chanorder'. For each channel and on separate lines, list the channel number, secondary redutcion rate and channel label.

    To determine the secondary reduction rate, decide for each displayed channel the desired display window time frame. For example, assume a 60 sec. window for channels 0 to 3 and a 180 sec. window for channel 4 (the fifth channel).

    From table H.1, the standard window time frame for 5 channels is 3.28 sec. A secondary reduction rate of 20 gives a window time frame of 64 seconds, and 55 gives 180.4 seconds. File 'chanorder' should contain:

```
00 0020 Twenty character label
01 0020    "         "        "
02 0020    "         "        "
03 0020    "         "        "
04 0055    "         "        "
```

3. Connect CLK0 'O' output to CLK1 'C' input. Attach
    CLK1 '1' output to the 'CLK' input on the AD12f
    converter. For single channel collections connect
    CLK0 'O' output directly to the converter.

4. Start DAADS. With the Unix system prompt on the
    screen, type in DAADS and hit return. The ex-
    ecutable DAADS program will start by presenting
    the Main Menu Module.

5. Select option 1, "Data collection a Display".

6. From the Data collection and Display Menu Module
    select option 1, "Use standard set-up file". If
    had wanted to enter session parameters interact-
    ively could have selected option 2.

7. Give standard set-up file name. This is the name
    of the file created earlier; Session_setup. The
    name given can be any legal file containing appro-
    priate session parameters.

8. With set-up complete, select option 3, "Collect
    data and display". This starts the physical data
    collection session.

9. When ready, start actual data storage by typing
    'W'. Keep in mind how much data will fit into
    available file space. Be careful not to overfill.

10. Type 'W' again to stop data storage or type 'Q' to
    quit and exit from DAADS.

With these steps an operator can accomplish a data

collection and display. However, DAADS contains three addi-

tional functions; Extract a channel, Replay a session, and

Perform data analysis. It is hoped these additional fun-

ctions will provide the means to make something useful out

of the data collected.

Appendix H

Understanding DAADS channel displays requires knowing the concept and importance of data reduction, how DAADS reduces the data for display, and the perceptual results in the display window.

Concept and Importance

The concept of data reduction is to lower the amount of data processing required by the host CPU. In fact if the host is required to process all the data collected it will run behind the data acquisition processor and cause the input buffers to queue up waiting to be emptied. When the queue becomes full, a message "Can't declare null buffer AST" indicates a system crash is imminent. Using data reduction prevents this system crash.

DAADS uses two levels of data reduction. The primary data reduction level applies to all input channels at a uniform rate. Also secondary data reduction applies to all input channels. However the reduction rate is user supplied for each channel within the channel order file as explained in appendix F.

Primary data reduction allows for a faster real-time sample rate. This sampling rate, fixed at 160 HZ. fills the input buffers quick enough to avoid long response times between signal generation and final display. Obviously, the 160 HZ or the buffer sizes can be lowered and still produce the same display results. However, the chosen sampling rate must stay fast enough

to meet the Nyquist sampling criterion.

Secondary data reduction provides channel independent data reduction. Using a secondary rate of one, means no further reduction after enforcing primary reduction. For either level, the data reduction affects only the data chosen for display.

Consequently the results from two levels of data reduction are selected data items placed into individual channel display buffers at a final effective sampling rate or the rate of displayed data.

Effective Sample Rate (ESR) Computation

Expected ESR. Suppose a single channel is physically sampled at 160 Hz, primary reduction is 10 (use 1 out of every 10 input) and the secondary reduction is 4. This means out of every tenth data item selected for display, use only the fourth one. Now the effective sampling rate is 4 Hz. If the DAADS primary reduction rate was a constant, say 10, then the expected effective sampling rate (ESR) could be computed by;

Expected
$$ESR = 160 \text{ Hz} * 1/10 * 1/4 \tag{1}$$

Unfortunately (1) does not reflect the actual calculation performed. Since the primary reduction rate used in DAADS is not constant but is based on the number of channels (nchans) collected for a particular session. The reduction rate used selects one frame of input channels (a

frame is a single grouping of all channels collected, 0,1,2,0,1,2,0,1,2 represents three frames of input data for channels 0, 1, and 2.) then skips a number of frames equal to the number of channels in a frame. For three channels, frame zero is selected then frame three, then frame six and so on until the input buffer is emptied. As a result the primary reduction rate is 1/nchans. Formula (1) now becomes;

$$\text{Expected ESR} = 160 \text{ Hz} \ast 1/\text{nchans} \ast 1/\text{secondary reduction} \qquad (2)$$

Unavoidably, a MASSCOMP data acquisition requirement forces an adjustment to the ESR. The MASSCOMP data acquisition routines must acquire an even number of data items into a single buffer. The problem then is to increase the input buffer to an even number of frames insuring an even number of data items collected per buffer. This increase in buffer size changes the expected ESR because the number of samples per buffer changes.

Adjusted ESR Computation. The adjusted ESR takes into account the time it takes to fill a single input buffer along with the number of sample data items selected for display from each input buffer. The time required to fill an input buffer depends on the buffer size and the collection rate of single data items (not frames).

H - 3

Assume an input buffer of size 192 data items and assume nchans of 16 channels. That means 12 frames of 16 channels in this buffer but still only 192 data items to fill the buffer. At 160 Hz input rate per channel, the number of data items collected in a second is (16 X 160) or 2560 data items. The buffer fills in (192 data items ÷ 2560 data items/sec) or .075 secs. Now using the primary reduction rate, it's possible to compute how many display samples are selected from within a buffer.

Recall from above, the buffer contains 12 frames of 16 channels each. Taking (12 frames ÷ 16 channels) gives .75 display samples. Rounding up to the nearest integer results in one display sample per input buffer and (1 sample per buffer ÷ .075 secs buffer fill time) gives 13.3 samples per second.

At this point 13.3 samples per second represents the display sample rate seen on the screen. Compare this to 160 samples per second of the original input rate and a data reduction becomes very apparent.

One last step remains in finding the final effective sample rate. The final computation must include the secondary reduction rate entered by the user for each channel. After having computed 13.3 samp/sec, divide by the secondary reduction rate or (13.3 ÷ secondary rate). If the secondary reduction is 1, nothing changes. With the secondary reduction at, say 2, the final effective sampling

rate becomes 6.05 samples per second.

The adjusted ESR formula becomes;

Adjusted
$$\text{ESR} = \frac{\text{\# of display samples per buffer}}{\text{input buffer fill rate}} \tag{3}$$

where

input buffer
$$\text{fill rate} = \frac{\text{\# of data items}}{\text{Actual sampling rate}} \tag{4}$$

and

$$\text{\# of display items} = \frac{\text{\# of buffer frames}}{\text{\# of channels collected}} \tag{5}$$
per buffer

Finally then, the ESR must also deal with the secondary reduction rate. So, the final ESR is;

$$\text{final ESR} = \text{Adjusted ESR} * \frac{1}{\begin{array}{c}\text{secondary}\\\text{reduction}\end{array}} \tag{6}$$

Table H.1 shows the expected and adjusted ESR for collecting one to 16 channels. Reaching the adjusted ESR requires knowlege of how many samples per buffer are selected for display and how long it takes to fill one input buffer. The final ESR is the adjusted ESR divided by the secondary reduction rate.

Perceptual Results

Also, table H.1 shows the time frame of all display windows using the adjusted ESR and where individual secondary reduction rates equal one (no secondary reduction).

H - 5
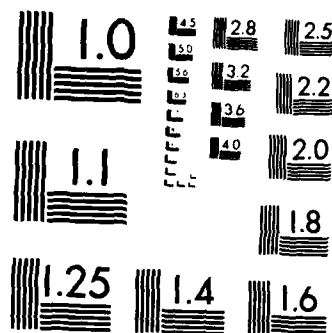
Display window time frame computation divides the total number of display slots (100) by the final ESR. For example, if the final ESR for channel 0 (displayed in window 0,) is 4 samples a second, then window 0 would spread across (100/4) or 25 seconds. In fact, every display window with a final ESR of 4 Hz would have a of 25 second time frame. The consideration of display window time frame becomes important in the selection of the secondary reduction rate.

The secondary reduction rate comes from the user through the channel order file. As such the user can "adjust" the window time frame by changing the secondary reduction rate and thus changing the final ESR. From table H.1 the window time frame for all display windows with four channels collected is 2.5 seconds.

With a secondary reduction rate of, say 4, on channel two the display window for channel two now represents 10 seconds, while the other three stay at 2.5 seconds (at a secondary reduction set to 1). Essentially, the time span of individual display windows can be set uniquely.

All display window time frames are identical except when the secondary reduction rate applied to a particular channel display window changes it. Table H.1 window time frame column shows the seconds for each display window with secondary reductions set to one. Selecting a secondary reduction rate to expand the time frame means finding an

integer to multiply the column entry by, which then in-
creases the time to the number of seconds desired. This
integer is the secondary data reduction rate for some
particular channel and when entered into the channel order
file (appendix F) it changes the time frame represented by
that channels display window.

Table H.1

Adjusted ESR and Window Time Frames

NCHANS	# OF BUFFER FRAMES	# OF EVEN FRAMES	# OF SAMPLES PER BUFF	ESR EXPECTED	ESR ADJUSTED	WINDOW TIME FRAME (SECS)
1	192	192	192	160	160	.625
2	96	96	48	80	80	1.25
3	64	64	21	53.3	52.5	1.99
4	48	48	12	40	40	2.50
5	38.4	38	7	32	30.4	3.28
6	32	32	5	26.6	25	4.00
7	27.4	28	4	22.8	22.8	4.00
8	24	24	3	20	20	5.00
9	21.3	22	2	17.7	15.4	6.50
10	19.2	20	2	16	16	6.25
11	17.4	18	2	14.5	17.7	11.22
12	16	16	2	13.3	20	5.00
13	14.7	16	2	12.3	20	5.00
14	13.7	14	1	11.4	11.4	8.70
15	12.8	14	1	10.6	11.4	8.70
16	12	12	1	10	13.3	7.50

Bibliography

1. CIM-100/-104/-108 RAM/PROM Expansion Boards Hardware Reference Manual. Santa Clara: National Semiconductor Corporation, 1982.

2. CIM-201 Serial I/O Board Hardware Reference Manual. Santa Clara: National Semiconductor Corporation, 1982.

3. CIM-411 Analog Input Board Hardware Reference Manual. Santa Clara: National Semiconductor Corporation, 1982.

4. CIM-602/-604 Card Cages User's Manual. Santa Clara: National Semiconductor Corporation, 1982.

5. CIM-660 Firmware Monitor User's Manual. Santa Clara: National Semiconductor Corporation, 1982.

6. CIM-801/-802/-804 CPU Board Hardware Reference Manual. Santa Clara: National Semiconductor Corporation, 1982.

7. Cowings, Patricia S. and William B. Toscano. "The Relationship of Motion Sickness Susceptibility to Learned Autonomic Control for Symptom Suppression," Aviation, Space, and Environmental Medicine,53: 570-575 (June 1982).

8. Collins, W.F. "Problems in Spatial Orientation; Vestibular Studies of Figure Skaters," Transcriptions of American Academy of Opithalogy and Otolarying,58: 575-578 (1966).

9. Earl, Capt Orville A. and Capt Charles N. Peterson. Physiological Data Acquisition System and Motion Sickness Prevention Trainer. MS Thesis. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1983 (AD-A138361).

10. Guedry, F.E. "Visual Control of Habituation to Complex Vestibular Stimulation in Man," American Academy of Opithalogy and Otolarying,58: 377-389 (1964).

11. Guiguard, J.C. and Michael E. McCauley. "Motion Sickness Induced by Complex Periodic Waveforms," Aviation, Space, and Environmental Medicine,53: 554-563 (June 1982).

12. Guyton A.C. "Movement of Food Through the Alimentary Tract," Textbook of Physiology, (Sixth Edition). Toronto: W.B. Saunders Company, 1981.

13. <u>Instruction Manual for the Autogen 1000</u>. Berkeley: Autogen Systems Corporation, 1975.

14. <u>Instruction Manual for the Autogen 1100</u>. Berkeley: Autogen Systems Corporation, 1975.

15. <u>Instruction Manual for the Autogen 3400</u>. Berkeley: Autogen Systems Corporation, date unknown.

16. <u>Instruction Manual for the Autogen 9400</u>. Berkeley: Autogen Systems Corporation, 1979.

17. Levy, Richard A. "Clinical Application Biofeedback," SAM-CR-80-249, Clinical Science Division, USAF School of Medicine, Brooks AFB TX (AD-A092-429).

18. Levy, Richard A. and others. "Biofeedback Rehabilitation of Airsick Aircrew," <u>Aviation, Space, and Environmental Medicine</u>, <u>52</u>: 118-121 (Feb 1981).

19. Luciani, Ralph J. and others. "The Acquisition and Validation of the Surface Electromyogram Signal for Evaluating Muscle Fatigue," <u>Aviation, Space, and Environmental Medicine</u>, <u>54</u>: 744-750 (Aug 1983).

20. Massachusetts Computer Corporation. <u>Graphics Applications Programming Manual</u> (Revision C). Boston: Massachusetts Computer Corporation, 1984.

21. Massachusetts Computer Corporation. <u>Data Acquisition Application Programming Manual</u> (Revision B). Boston: Massachusetts Computer Corporation, 1983.

22. Massachusettes Computer Corporation. <u>DA/CP Software Library (SP-50) Release Notes</u> (Revision 0.4). Boston: Massachusetts Computer Corporation, 1983.

23. Mathog, R.H. and R.L. Cramer. "Testing of the Vestibular System," <u>Aerospace Medicine</u>, <u>42</u>: 741-745 (1971).

24. Phillips, Chandler A. and Jerrold S. Petrolfsky. "Quantitative Electromyography; Response of the Neck Muscles to Conventional Helmet Loading," <u>Aviation, Space, and Environmental Medicine</u>, <u>54</u>: 452-457 (May 1983).

25. Schuster, M.M. "Disorders of Motility," <u>Textbook of Medicine</u> (15th Edition). New York: Beeson-McDermott, 1979.

26. Toscano, William B. and Patricia S. Cowings. "Reducing Motion Sickness; A Comparision of Autogenic Feedback Training and an Alternative Cognitive Task," <u>Aviation</u>, <u>Space</u>, <u>and</u> <u>Environmental</u> <u>Medicine</u>, <u>53</u>: 449-453 (May 1982).

27. Wood, C. D. and A. Graybiel. "The Theory of Antimotion Sickness Drug Mechanisms," <u>Aviation</u>, <u>Space</u>, <u>and</u> <u>Environmental</u> <u>Medicine</u>, <u>43</u>: 249-252 (March 1972).

VITA

Captain Douglas G. Fitzpatrick was born in Lynwood CA. 18 Jan 1950. He attended school in Paramount CA. and graduated with honors from Paramount High School in June 1968. In October 1971, Capt Fitzpatrick enlisted in the Air Force. After graduating from his 36-week technical training school in September 1972, he began his career at Vandenberg AFB CA. as an Electronic Communications Cryptographic Equipment repairman. During his assignment to Lackland AFB TX. Capt Fitzpatrick earned a B.A. in Computer Science. This degree lead to his commissioning and subsequent reassignment to Keesler AFB MS in May of 1979. Then, after four years teaching applications programming and operating systems concepts, Capt Fitzpatrick entered the School of Engineering Air Force Institute of Technology, in May 1983.

Permanent address: 11720 Utah Ave.

South Gate, CA 90280

VITA

Captain Michael A. Rogers was born on February 14, 1957 in Bitburg, West Germany. He graduated from high school in Jacksonville, Arkansas in 1975 and attended the University of Arkansas from which he received the degree of Bachelor of Science of Electrical Engineering in June 1980. Upon graduation, he received a commission in the USAF through the ROTC program. After completing a six-month course in communications engineering at Keesler AFB, Mississippi he was assigned to the Engineering Installation Center at Tinker AFB, Oklahoma. There he served as an outside plant telephone scheme engineer until May 1983 when he was assigned to AFIT's School of Engineering at Wright-Patterson AFB, Ohio.

Permanent address: 341 Medinah Lane
Lompoc, CA 93436

VITA

Captain Robert Williams was born on May 22, 1953 in Seoul, South Korea. He graduated from Junction City High School in Junction City, Kansas in May 1972 and enlisted in the United States Air Force in July 1972. He was selected for the Airman's Education and Commissioning Program in 1977 and in December 1979 he received a Bachelor of Science Degree in Electrical Engineering from Kansas State University. Upon graduation he attended the Air Force Officer Training School and in April 1980 he was commissioned as a second lieutenant.

After commissioning he was assigned to the Electronic Security Command at Ft. George G. Meade, Maryland where he served as a Special Collection Systems Design Engineer for the National Security Agency's Operations Organization. In May 1983 he was assigned to the Air Force Institute of Technology, Wright-Patterson AFB, Ohio.

<div align="right">

Permanent address: 217 East 15th Street

Junction City, KS 66441

</div>

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.			
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GE/GCS/ENG/84D-30		5. MONITORING ORGANIZATION REPORT NUMBER(S)			
6a. NAME OF PERFORMING ORGANIZATION School of Engineering	6b. OFFICE SYMBOL (If applicable) AFIT/ENG	7a. NAME OF MONITORING ORGANIZATION			
6c. ADDRESS (City. State and ZIP Code) Air Force Institute of Technology Wright-Patterson AFB, OH 45433		7b. ADDRESS (City, State and ZIP Code)			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION USAF School of Aerospace Medicine	8b. OFFICE SYMBOL (If applicable) USAF/SAM	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER			
8c. ADDRESS (City, State and ZIP Code) Brooks AFB, TX 78235		10. SOURCE OF FUNDING NOS.			
		PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
11. TITLE (Include Security Classification) See Box 19					

12. PERSONAL AUTHOR(S) See Box 19				
13a. TYPE OF REPORT MS Thesis	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Yr., Mo., Day) 1984 December	15. PAGE COUNT 202	
16. SUPPLEMENTARY NOTATION				

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	Motion Sickness, Biofeedback, Physiological,
06	19		Biophysical

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Title: COMPUTERIZED BIOPHYSICAL DATA ACQUISITION SYSTEM FOR
MOTION SICKNESS STUDIES

Thesis Advisor: Dr Matthew Kabrisky

Authors: Douglas G. Fitzpatrick, B.A., Capt USAF
Michael A. Rogers, B.S.E.E., Capt, USAF
Robert Williams, B.S.E.E., Capt, USAF

Approved for public release: IAW AFR 190-17

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL Dr Matthew Kabrisky	22b. TELEPHONE NUMBER (Include Area Code) 513-255-5276	22c. OFFICE SYMBOL AFIT/ENG

DD FORM 1473, 83 APR   EDITION OF 1 JAN 73 IS OBSOLETE.   UNCLASSIFIED

A biophysical data acquisition system was integrated with a MASSCOMP MC500 computer to provide the foundation for a computerized motion sickness rehabilitation program.

A user-friendly data acquisition system was developed to process several different channels of biophysical information from a subject. This system processes the data to create graphics for operator interaction on a real-time basis and stores data for later retrieval and analysis.

The electrical schematics and frequency responses of the fabricated physiological monitoring equipment used to measure heart rate, gastric motility, respiration rate, skin pallor, intestinal tone, and eye movement were completed.

END

FILMED

5-85

DTIC